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EIGHTH REPORT

OF

THE MICHIGAN ACADEMY OF SCIENCE

CONTAINING AN ACCOUNT OF THE ANNUAL MEETING

HELD AT

ANN ARBOR, MARCH 29, 30 AND 31, 1906.

PREPARED UNDER THE DIRECTION OF THE COUNCIL

BY

E. E. BOGUE
SECRETARY

AND

WALTER G. SACKETT
ASSISTANT SECRETARY

BY AUTHORITY

LETTER OF TRANSMITTAL

To Honorable Fred M. Warner, *Governor of the State of Michigan:*

Sir—I have the honor to submit herewith the Eighth Annual Report of the Michigan Academy of Science for publication in accordance with Section 14 of Act No. 44 of the Public Acts of the Legislature of 1899.

Respectfully,

E. E. Bogue,

Secretary of The Michigan Academy of Science.

Agricultural College, May 1, 1906.

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CONSTITUTION

OF

THE MICHIGAN ACADEMY OF SCIENCE.*

ARTICLE I.

This Society shall be known as "THE MICHIGAN ACADEMY OF SCIENCE."

ARTICLE II: OBJECTS.

The objects of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science.

ARTICLE III: MEMBERSHIP.

The Academy shall be composed of *Resident Members, Corresponding Members, Honorary Members and Patrons.*

1. Resident Members shall be persons who are interested in scientific work and resident in the State of Michigan.
2. Corresponding Members shall be persons interested in science, and not resident in the State of Michigan.
3. Honorary Members shall be persons distinguished for their attainments in science, and not resident in the State of Michigan, and shall not exceed twenty-five in number.
4. Patrons shall be persons who have bestowed important favors upon the Academy, as defined in Chapter I, Paragraph 4 of the By-Laws.
5. Resident Members alone shall be entitled to vote and hold office in the Academy.

ARTICLE IV: OFFICERS.

1. The officers of the Academy shall consist of a President, a Vice President of each Section that may be organized, a Secretary, and a Treasurer.

These officers and all past presidents shall constitute an Executive Committee, which shall be called the *Council.*

2. The PRESIDENT shall discharge the usual duties of a presiding officer at all meetings of the Academy, and of the Council. He shall take cognizance of the acts of the Academy and of its officers, and cause the provisions of the Constitution and By-Laws to be faithfully carried into effect. He shall also give an address to the Academy at the closing meeting of the year for which he is elected.
3. The duties of the President in case of his absence or disability shall be assumed by one of the Vice Presidents who shall be designated by the Council.

The VICE PRESIDENTS shall be chairmen of their respective Sections. They shall encourage and direct research in the special branches of science included within the Sections over which they preside.

4. The SECRETARY shall keep the records of the proceedings of the Academy, and a complete list of the members, with the dates of their election and disconnection with the Academy. He shall also be the Secretary of the Council.

The SECRETARY shall co-operate with the President in attending to the ordinary affairs of the Society. He shall attend to the preparations, printing and mailing of circulars, blanks, and notifications of elections and meetings. He shall superintend other printing ordered by the Academy, or by the President, and shall have charge of its distribution under the direction of the Council.

* The history of the Academy will be found in full in the First Annual Report.

The SECRETARY, unless other provision be made, shall also act as *Editor* of the publications of the Academy and as *Librarian* and *Custodian* of property.

5. The TREASURER shall have the custody of all funds of the Academy. He shall keep an account of receipts and disbursements in detail, and this account shall be audited as hereinafter provided.

6. The Academy may elect an *Editor* to supervise all matters connected with the publication of the transactions of the Academy, under the direction of the Council, and to perform the duties of Librarian until such time as the Academy shall make that an independent office.

7. The COUNCIL is clothed with executive authority, and with the legislative powers of the Academy in the intervals between the latter's meetings; but no extraordinary act of the Council shall remain in force beyond the next following stated meeting, without ratification by the Academy. The Council shall have control of the publications of the Academy, under the provisions of the By-Laws and of the resolutions from time to time adopted. It shall receive nominations for members, and on approval, shall submit such nominations to the Academy for action. It shall have power to fill vacancies *ad interim*, in any of the offices of the Academy.

8. TERMS OF OFFICE. The *President* and *Treasurer* shall be elected annually, and shall not be eligible to re-election for an interval of three years after retiring from office. The *Vice Presidents*, *Secretary*, and the *Editor* shall be elected annually and be eligible to re-election without limitation. [Section 8 was amended April 1, 1898, to read as follows: The President, Vice Presidents, Secretary, Treasurer, and Editor shall be elected annually, and be eligible to re-election without limitation.]

ARTICLE V: VOTING AND ELECTIONS.

1. *All elections* shall be by ballot. To elect a Resident Member, Corresponding Member, Honorary Member, or Patron or impose any special tax shall require the assent of three-fourths of all Resident Members voting.

2. Any member may be expelled by a vote of nine-tenths of all members voting, provided notice that such a movement is contemplated be given at a meeting of the Academy three months previous to such action.

3. ELECTION OF MEMBERS. Nominations for Resident membership shall be made by two Resident Members, according to a form to be provided by the Council. One of these Resident Members must be personally acquainted with the nominee and his qualifications for membership. The Council shall submit the nominations received by them, if approved, to a vote of the Academy at a regular meeting.

4. ELECTION OF OFFICERS. Nominations for office shall be made by the Council as provided in the By-Laws. The nominations shall be submitted to a vote of the Academy at its winter [Annual] meeting. The officers thus elected shall enter upon duty at the adjournment of the meeting.

5. At the meeting in which this Constitution is adopted the officers for the ensuing year shall be elected in such manner as the Academy may determine.

ARTICLE VI: MEETINGS.

1. The Academy shall hold at least two stated meetings a year—a *Summer* [*or Field*] *Meeting*, and a *Winter* [*or Annual*] *Meeting*. The date and place of each meeting shall be fixed by the Council, and announced by circular at least three months before the meeting. The programme of each meeting shall be determined by the Council, and announced beforehand, in its general features. The details of the daily sessions shall also be arranged by the Council.

2. All members must forward to the Secretary, if possible, before the convening of the Academy, full title of all papers which they propose to present during the meeting, with a statement of the time that each will occupy in delivery and a brief abstract of their contents. From the abstracts thus presented, the Council will determine the fitness of the paper for the programme.

3. This section stricken out April 1, 1898.

4. SPECIAL MEETING of the Academy may be called by the Council, and must be called upon the written request of twenty Resident Members.

5. STATED MEETINGS OF THE COUNCIL, shall be held coincidently with the stated meetings of the Academy. Special meetings of the Council may be called by the President at such times as he may deem necessary.

6. QUORUM. At meetings of the Academy a majority of those registered in

attendance shall constitute a quorum. Four members shall constitute a quorum of the Council.

ARTICLE VII: Publications.

The publications of the Academy shall be under the immediate control of the Council, but the Council shall accord to each author the right, under proper restrictions, to publish through whatever channel he may choose.

ARTICLE VIII: Sections.

1. Members not less than eight in number may by special permission of the Academy unite to form a Section for the investigation of any branch of science. Each Section shall bear the name of the science which it represents, thus: The Section of (Agriculture) of The Michigan Academy of Science.
2. Each Section is empowered to perfect its own organization as limited by the Constitution and By-Laws of the Academy.

ARTICLE IX: Amendments.

This Constitution may be amended at any Winter [Annual] meeting by a three-fourths vote of all the Resident Members present.

BY-LAWS.

CHAPTER I: Membership.

1. No person shall be accepted as a Resident Member unless he pay the dues for the year, within three months after notification of his election. The annual dues shall be one (1) dollar, payable on or before the annual meeting in advance; but a single pre-payment of twenty-five (25) dollars shall be accepted as commutation for life.
2. The sums paid in commutation of dues shall be invested, and the interest used for the ordinary purposes of the Academy during the payer's life, but after his death the sum shall be covered into the Research Fund.
3. An arrearage in payment of annual dues shall deprive a Resident Member of the privilege of taking part in the management of the Academy and of receiving the publications of the Academy. An arrearage continuing over two (2) years shall be construed as notification of withdrawal.
4. Any person eligible under Article III of the Constitution, may be elected Patron upon the payment of one hundred (100) dollars to the Research Fund of the Academy.

CHAPTER II: Officals.

1. The President shall countersign, if he approves, all duly authorized accounts and orders drawn on the Treasurer for the disbursement of money.
2. The Secretary, until otherwise ordered by the Academy, shall perform the duties of Editor, Librarian, and Custodian of the property of the Society.
3. The Academy may elect an Assistant Secretary.
4. The Treasurer shall give bonds, with two good sureties approved by the Council, in the sum of five hundred dollars, for the faithful and honest performance of his duties, and the safe-keeping of the funds of the Academy. He may deposit the funds in bank at his discretion, but shall not invent them without the authority of the Council. His accounts shall be balanced on the first day of the Annual Meeting of each year.
5. The minutes of the proceedings of the Council shall be subject to call by the Academy.

CHAPTER III: Election of Members.

1. Nominations for Resident Membership may be proposed at any time on blanks to be supplied by the Secretary.
2. The *form* for the nomination of Resident Members shall be as follows:

In accordance with his desire, we respectfully nominate for Resident Member of The Michigan Academy of Science.

(Full name)

(Address)

(Occupation)

(Branch of Science interested in, work already done, and publications if any)

(Signed by at least two Resident Members)

The form when filled is to be transmitted to the Secretary.

3. The Secretary shall bring all nominations before the Council at either the winter [Annual] or summer [Field] meeting of the Academy, and the Council shall signify its approval or disapproval of each.

4. At the same or next stated meeting of the Academy, the Secretary shall present the list of candidates to the Academy for election.

5. Corresponding Members, Honorary Members, and Patrons shall be nominated by the Council, and shall be elected in the same manner as Resident Members.

CHAPTER IV: Election of Officers.

Section 1. At the Annual Meeting the election of officers shall take place, and the officers elected shall enter on their duties at the end of the meeting.

Section 2. The Council shall nominate a candidate for each office, but each Section may recommend to the Council a candidate for its Vice President. Additional nominations may be made by any member of the Academy. All elections shall be made by ballot.

CHAPTER V: Financial Methods.

1. No pecuniary obligation shall be contracted without express sanction of the Academy or the Council. But it is to be understood that all ordinary incidental and running expenses have the permanent sanction of the Academy, without special action.

2. The creditor of the Academy must present to the Treasurer a fully *itemized* bill, *certified* by the official ordering it, and *approved* by the President. The Treasurer shall then pay the amount out of any funds not otherwise appropriated, and the receipted bill shall be held as his voucher.

3. At each annual meeting, the President shall call upon the Academy to choose two members, not members of the Council, to whom shall be referred the books of the Treasurer, duly posted and balanced to the first day of the Annual Meeting as specified in the By-Laws, Chapter II, Paragraph 4. These Auditors shall examine the accounts and vouchers of the Treasurer, and any member or members of the Council may be present during the examination. The report of the Auditors shall be rendered to the Academy before the adjournment of the meeting and the Academy shall take appropriate action.

CHAPTER VI: Publications.

1. The publications are in charge of the Council and under their control, limited only as given by Article VII, of the Constitution.

2. One copy of each publication shall be sent to each Resident Member, Corresponding Member, Honorary Member, and Patron, and each author shall receive fifty copies of his memoir. This provision shall not be understood as including publications in journals not controlled by the Academy. [By recent ruling, authors receive no reprints free. If reprints are wanted the Academy will pay two-thirds if the author pays one-third the cost of printing not to exceed fifty copies. The author may have as many more than fifty provided he bears the whole expense of those above fifty. (Minutes of 1906.)

CHAPTER VII: The Research Fund.

1. The Research Fund shall consist of moneys paid by the general public for publications of the Academy, of donations made in aid of research, and of the sums paid in commutation of dues according to the By-Laws, Chapter I, Paragraphs 2 and 4.

2. Donors to this fund not Members of the Academy, in the sum of twenty-five dollars, shall be entitled without charge, to the publications subsequently appearing.

CHAPTER VIII: ORDER OF BUSINESS.

1. The order of business at the Winter [Annual] Meetings shall be as follows:
(1) Call to order by the Presiding Officer.
(2) Introductory ceremonies.
(3) Statements by the President.
(4) Report by the Council.
(5) Report of the Treasurer, and appointment of the Auditing Committee.
(6) Election of officers of the next ensuing Administration.
(7) Election of Members.
(8) Announcement of the hour and place for the Address of the retiring President.
(9) Necrological notices.
(10) Miscellaneous announcements.
(11) Business motions and resolutions, and disposal thereof.
(12) Reports of Committees and disposal thereof.
(13) Miscellaneous motions and resolutions.
(14) Presentation of memoirs.

2. At an *adjourned session*, the order shall be resumed at the place reached on the previous adjournment, but new announcements, motions and resolutions, will be in order before the resumption of the business pending at the adjournment of the last preceding session.

3. At the SUMMER [FIELD] MEETING the items of business under numbers (5), (6), (8), (9), shall be omitted.

4. At any SPECIAL MEETING the Order of Business shall be (1), (2), (3), (7), (10), followed by the special business for which the meeting was called.

CHAPTER IX: AMENDMENTS.

These By-Laws may be amended by a majority vote of the members present at any regular meeting.

OFFICERS 1906-1907.

President, Dr. J. B. POLLOCK, Ann Arbor.
Secretary-Treasurer, Prof. E. E. BOGUE, Agricultural College.
Assistant Secretary, WALTER G. SACKETT, Agricultural College.
Librarian, Dr. G. P. BURNS, Ann Arbor.
Editor of Bulletin, Prof. E. E. BOGUE, Agricultural College.

VICE-PRESIDENTS.

Agriculture, Prof. R. S. SHAW, Agricultural College.
Botany, Prof. C. A. DAVIS, Ann Arbor.
Geography and Geology, Prof. R. D. CALKINS, Mt. Pleasant.
Sanitary Science, Prof. A. J. PATTEN, Agricultural College.
Science Teaching, Prof. S. O. MAST, Holland.
Zoology, Mr. C. C. ADAMS, Ann Arbor.

COUNCIL.

The Council is composed of the above named officers and all Past-Presidents, who are as follows:
Prof. W. J. BEAL, Agricultural College.
Prof. W. H. SHERZER, Ypsilanti.
BRYANT WALKER, ESQ., Detroit.
Prof. V. M. SPALDING, Witch Creek, Cal.
Dr. HENRY B. BAKER, Lansing.
Prof. JACOB E. REIGHARD, Ann Arbor.
Prof. CHARLES E. BARR, Albion.
Prof. V. C. VAUGHAN, Ann Arbor.
*Prof. I. C. RUSSELL, Ann Arbor.
Prof, F. C. NEWCOMBE, Ann Arbor.
Dr. A. C. LANE, State Geologist, Lansing.
Prof. W. B. BARROWS, Agricultural College.

* Deceased.

MEMBERSHIP OF THE MICHIGAN ACADEMY OF SCIENCE.

April 20, 1906.

* Charter member; † Honorary member; ‡ Corresponding member.

Adams, Charles C., Ann Arbor.
Alexander, Samuel, Ann Arbor.
Anderson, Crosby A., Agricultural College.
Bach, Ellen Botsford, Agricultural College.
*Baker, Henry B., Lansing.
*Barr, Charles E., 111 Oswego St., Albion.
‡Barlow, Bronson, Guelph, Canada.
*Barrows, Walter B., Agricultural College.
‡Bastin, E. S., U. S. Geological Survey, Washington, D. C.
*Beal, Wm. J., Agricultural College.
‡Bell, Albert T., University Place, Nebraska.
Bennet, A. C. Coldwater.
Berger, Henry W., Ann Arbor.
Bigelow, S. L., Ann Arbor.
Bissell, J. H., Bank Chambers, Detroit.
Blain, Dr. Alexander W., Jr., 131 Elmwood Ave., Detroit.
Bogue, E. E., Agricultural College.
*Bovie, W. T., (Ann Arbor), Yellow Springs, Ohio.
Brenton, Samuel, 121 Alexandrine Ave., Detroit.
Bretz, J. H., Flint.
Bricker, J. I., Saginaw, West Side.
Brotherton, Wilfred A., Rochester.
Brown. Dr. R. A., 413 West Dutton St., Kalamazoo.
‡Bullock, B. S., Casilla, Mission Auncania, Jennico, Chili, S. A.
Burnham, Ernest, 509 South Rose St., Kalamazoo.
Burns, G. P., Ann Arbor.
Calkins, R. D., Central Normal School, Mt. Pleasant.
Carrow, Fleming, M. D., The Balmo, Detroit.
Charlton, Orlando, Kalamazoo.
Christian, Dr. A. M., Pontiac.
‡Clark, Hubert L., Museum of Comparative Zoology, Cambridge, Mass
Clark, L. T., Parke, Davis & Co., Detroit.
‡Clawson, A. B., Madison, Wis.
‡Cole, Leon J., 37 Mellen St., Cambridge, Mass.
Collin, Henry P., Coldwater.
*Connor, Leartus, M. D., 91 Lafayette Ave., Detroit.
Cooper, William S., 1015 Jefferson Ave., Detroit.
Cooper, W. F., Lansing, Mich., Box 244.
*Courtis, W. M., 706 Hammond Building, Detroit.
‡Cowgill, Paul A., Michigan City, Indiana.
Crane, Augustus W., M. D., Kalamazoo.
Crane, Caroline-Baretlett, Kalamazoo.
Dachnowski, Alfred, Ann Arbor.
Dandeno, J. B., Agricultural College.
Davies, M. L., Bay City.
*Davis, Chas. A., Ann Arbor.
Dawson, Jean, 2093 Ingalls St., Ann Arbor.
‡Denton, Mina C., Milwaukee, Wis.
*Dodge, Chas. K., Port Huron.
Doty, Jessie R., Alma.
‡Duerden, J. E., Grahamstown, Cape Colony, South Africa.

Dunbar, Francis J., 322 South 5th St., Ann Arbor.
Dunphy, Geo. W., Quincy, Mich.
‡Edwards, S. F., Guelph, Ontario, Canada.
*Farwell, O. A., 784 Congress St. East, Detroit.
Fischer, Dr. O. E.. 507 Field Ave., Detroit.
Frapwell, A. P., Ann Arbor.
Gilmore, Gertrude A., 27 Charlotte Ave., Detroit.
Goddard, Mary A., 516 Adams St., Ypsilanti.
Gordon, W. C., Houghton.
‡Gregory, Wm. M., 25 Olive Place, Cleveland, Ohio.
Grove, J. M., Hillsdale.
Hagle, Florence, 618 Packard St., Ann Arbor.
‡Hall, Asaph, Naval Observatory, Washington, D. C.
Hang, Bernice L., 1130 Third Ave., Detroit.
‡Hankinson, Thomas L., Charleston, Ill.
‡Harton, R. E., 75 Arcade, Utica, New York.
Harvey, Caroline, 51 Winder St., Detroit.
Harvey, Nathan A., Ypsilanti.
Haynes, Julia A., Kalamazoo.
Hibbard, R. P., Botanical Laboratory, Ann Arbor.
Hinsdale, W. B., Ann Arbor.
‡Holt, W. P., 1004 Jefferson Ave., Toledo, Ohio.
Hornbeck, H. N., Traverse City.
Hubbard, Dr. Lucinia L., Painesdale, Houghton County, Mich.
Hunt, Wm. F., Ann Arbor.
Jamieson, Clara O., Ann Arbor.
Jefferson, M. S. W., 14 Normal St., Ypsilanti.
Jeffery, J. A., Agricultural College.
Johnson, Ora O., 126 Miami Ave., Detroit.
‡Johnston, J. B., Morganstown, W. Va.
Jopling, Wm., V. S., Owosso.
Kauffman, C. H., Ann Arbor
Kiefer, Guy L., M. D., Detroit.
King, Mrs. Louisa, Alma.
King, Francis, Alma.
‡Kofoid, Chas. A., Berkeley, Cal.
Kraus, Edward H., 548 Thompson St., Ann Arbor.
‡Lander, Clarence H., 89 Arlington St., Cleveland, Ohio.
*Lane, A. C., Lansing.
Leverett, Frank, Ann Arbor.
‡Lillie, Frank R., University of Chicago, Illinois.
‡Leow, L. A., Ubee, Huntington County, Indiana.
Lombard, Warren P., Ann Arbor.
Lovejoy, P. L., Ann Arbor.
Lyons, Albert B., M. D., 72 Brainard St., Detroit.
Magee, M. J., Sault Ste. Marie.
Magers, S. D., Ypsilanti.
*Manton, W. P., M. D., 32 Adams St., Detroit.
Marshall, Chas. E., Agricultural College.
Marston, Hon. T. F., Bay City.
Mast, Samuel O., Holland.
McStanton, Samuel, Ann Arbor.
‡Munson, Wm. H., 112 East King St., Winona, Minn.
‡Mumaw, H. A., Elkhart, Ind.
Murbach, Louis, 950 Cass Ave., Detroit.
Myers, J. J., Agricultural College.
‡Nattress, Rev. Thomas, Amherstburg, Ontario.
Nellist, John F., Grand Rapids.
*Newcombe, Frederick C., Ann Arbor.
Newman, Dr. H. H., Ann Arbor.
Notestein, Frank N., Alma.
Novy, Frederick G., Ann Arbor.
Patten, A. J., Agricultural College.
Pearl, Raymond, Ann Arbor.

Pennington, L. H., Ann Arbor.
Pettee, Edith Ellen, 83 Harper Ave., Detroit.
Pettit, Rufus H., Agricultural College.
Phelps, Jessie, 429 North Adams St., Ypsilanti.
Pierce, Miss Ida, 68 Frelinghysen Ave., Battle Creek.
Pollock, J. B., 922 Church St., Ann Arbor.
Praeger, Wm. E., Kalamazoo.
‡Reed, H. S., University of Missouri, Columbia, Missouri.
*Reighard, Jacob, Ann Arbor.
Robinson, Flyd W., Agricultural College.
*Russell, Israel C., LL. D., 1703 Hill St., Ann Arbor.
Ruthven, A. G., Jr., 821 East Ann St., Ann Arbor.
Sackett, Walter G., Agricultural College.
Sargent, Herbert E., Grand Rapids.
Seaman, A. E., Houghton.
Shaw, R. S., Agricultural College.
*Sherzer, Wm. H., Ypsilanti.
Shull, A. Franklin, 1017 Vaughan St., Ann Arbor.
Smith, Bertram G., Ann Arbor.
‡Smith, Harlan I., 77th St. and Central Park, New York.
Smith, Chas. E., 108 North Saginaw St., Pontiac.
*Spalding, Volney M., Ph.D., Witch Creek, Cal.
Sperr, Frederick W., Box 277, Houghton.
*Stearns, Francis L., Adrian.
Streng, Louis H., 355 North Prospect St., Grand Rapids.
*Strong, E. A., Ypsilanti.
‡Taylor, F. B., Home Ave., Fort Wayne, Ind.
Thompson, Harriet W., Port Sanilac.
Transeau, E. N., Alma.
Vaughan, Victor C., M. D., LL. D., Ann Arbor.
Vaughan, V. C., Jr., M. D., 1939 Woodward Ave., Detroit.
Walker, Bryant, 16 Moffat Block, Detroit.
Wallace, Wm. T., Hastings.
‡Ward, Henry B., University of Nebraska, Lincoln, Nebraska.
Warren, Lewis E., 19 University Place, New York City.
*Watkins, Hon. L. Whitney, Manchester.
Wetmore, Mary, M. D., Agricultural College.
‡Wheeler, Chas. F., Bureau of Plant Industry, Washington, D. C.
*Wheeler, E. S., Jones Building, Detroit.
‡Wheeler, Mrs. Mark, Fort McKinley, Manilla, P. I.
Whittaker, C. C., Orchard Lake.
Wilbur, Cressey L., M. D., Lansing.
Williams, Gardner S., Ann Arbor.
*Williams, Mortimer, M. D., Sixth and Water Sts., Port Huron.
Wilson, Wm., M. D., Coldwater.
Wood, L. H., Kalamazoo.
Wood, Norman A., 1216 South University Ave., Ann Arbor.
‡Wolcott, Dr. Robt., Lincoln, Nebraska.
‡Worcester, D. C., Manilla, P. I.
Wright, L. L., Hon., Ironwood, Mich.
Wright, W. R., Stillwater, Okla.
Wyman, Thos. B., Negaunee.

SECRETARY-TREASURER'S REPORT.

Twelve persons were received into the membership of the Academy from April first, 1905, to April first, 1906. During the same period two members resigned, two were dropped for non-payment of dues, and one died, making an increase of seven during the year. The number of members at the time this report goes to press is 171.

A meeting of the Council was held at Jackson, November 25. At that meeting several matters of importance were considered. It was decided to hold the session of the Agricultural Section at the Agricultural College. The arrangement of papers in the report, regulation in regard to manuscripts, and the time for submitting manuscripts for the report were determined. Mr. Chas. C. Adams was made Vice-President of the Section of Zoology in place of Dr. J. E. Duerden, resigned. Professor E. E. Bogue was made Secretary-Treasurer vice Dr. C. E. Marshall, resigned.

The accounts of the treasury show that during the fiscal year ending March 31st, $228.81 were received and $158.49 were paid out, leaving a balance of $64.32 April 1, 1906.

LIST OF PAPERS PRESENTED AT THE ELEVENTH ANNUAL MEETING OF THE MICHIGAN ACADEMY OF SCIENCE.

Presidential Address—"Fact and Fancy in Bird Migration," Prof. W. B. Barrows.

1. Recent Studies on the Cross Pollination of Orchard Fruits, Prof. S. W. Fletcher.
2. Some Botanical Errors Found in Agricultural and Chemical Text Books, Prof. W. J. Beal.
3. Some Notes on Nodules, Director C. D. Smith.
4. (a) Vitality in Milk; (b) Von Behring's Plan for Immunizing Cattle Against Tuberculosis, Prof. C. E. Marshall.
5. Redfield's Theory of Heredity, Prof. G. A. Waterman.
6. Aërating Systems in Plants, Prof. J. B. Dandeno.
7. The Protein Content of Wheat as an Index to its Bread-Making Qualities, A. J. Patten.
8. The Occurrence of Benzoic Acid in Fruits, Prof. F. S. Kedzie.
9. Some of the Latest Points Concerning the Improvement of Corn, Prof. J. A. Jeffery.
10. Direction of Social Activities in Agricultural Communities, Ernest Burnham.
11. Specific Variations of Roots on the Centrifuge, F. C. Newcombe, Ann Arbor, ten minutes.
12. Seasonal Variation of Stored Foods in Trees, Frank J. Phillips, Ann Arbor, ten minutes.
13. A Stimulus to the Production of Cellulose and Starch, J. B. Dandeno, Agricultural College, fifteen minutes.
14. Variations in the Bibro-Vascular System of Certain Economic Plants, Miss Ellen B. Bach, Agricultural College, ten minutes.
15. Response of Stems to Tension, R. P. Hubbard, Ann Arbor, ten minutes.
16. The Relation of the Impervious Layer to the Distribution of Plants, G. P. Burns, Ann Arbor, fifteen minutes.
17. Vegetation of the Yosemite Region, California, E. N. Transeau, Alma, fifteen minutes.
18. The variation in Ground Water Level in a Bog, and its Relation to Vegetation, Harold Steele, South Haven, fifteen minutes.
19. Unreported Michigan Fungi for Petoskey, Detroit aud Ann Arbor, C. H. Kauffman, Ann Arbor, fifteen minutes.
20. *Didymaria Perforans* (*Marsonia perforans Ellis*), A Disease of Greenhouse Lettuce, J. B. Dandeno, Agricultural College, fifteen minutes.
21. Variation on Different Culture Media of a Species of *Fusarium*, J. B. Pollock, Ann Arbor, fifteen minutes.
22. Conditions Inducing the Formation of Reproductive Organs in Marchantia, Alfred Dachnowski, Ann Arbor, ten minutes.
23. A List of Michigau Algæ, J. B. Pollock, Ann Arbor, ten minutes.
24. The Genus *Annularia* in Michigan, O. E. Fischer, Ann Arbor, ten minutes.
25. Some Undescribed Species of Fungi, and Species Not Previously Reported from the State, J. B. Pollock, Ann Arbor, fifteen minutes.
26. Preliminary Notes on Plants of the Upper Peninsula, C. A. Davis, Ann Arbor, twenty-five minutes.
27. Culture Studies of Certain Fungi, C. H. Kauffman, Ann Arbor, ten minutes.
28. The Distribution of Plants in Mud Lake, L. H. Penniugton, Ann Arbor.
29. Some Notes Regarding the Variation of Rudbeckia hirta, Linn., W. J. Beal, Agricultural College.

30. Topographic Influence on Rainfall in Great Lakes Region, M. S. W. Jefferson, Ypsilanti, thirty minutes.
31. Glacial Features Between Crystal Falls and Menominee, I. C. Russell, Ann Arbor, fifteen minutes.
32. Glacial Features of the Eastern Part of the Northern Peninsula, Frank Leverett, Ann Arbor, twenty minutes.
33. Earthquakes of Keweenaw Point, A. C. Lane, Lansing, ten minutes.
34. Waters of Copper Mines, A. C. Lane, Lansing, ten minutes.
35. Relation of Moraines to Imlay Outlet, F. B. Taylor, Fort Wayne, Ind., fifteen minutes.
36. Raised Beaches of Eastern Wisconsin, (Illustrated), Walter Goldthwait, Evanston, Ill., twenty minutes.
37. Raised Beaches on the North Side of Saginaw Bay, W. M. Gregory, Cleveland, fifteen minutes.
38. Deformation of Nipissing Shore Line, F. B. Taylor, Fort Wayne Ind., fifteen minutes.
39. Geological Conditions of Municipal Water Supplies in Michigan, Frank Leverett, Ann Arbor, Michigan, twenty minutes.
40. Sanitary conditions of Municipal Water Supplies in Michigan, V. C. Vaughan, Ann Arbor, thirty minutes.
41. Shall Pollution of Michigan Streams be Permitted? Marshall O. Leighton, Washington, D. C., thirty minutes.
42. Purification of Municipal Water Supplies, Gardner S. Williams, Ann Arbor, thirty minutes.
43. Ideal Conditions for a Water Supply, I. C. Russell, Ann Arbor, twenty minutes.
44. The Work of the Pasteur Institute, J. G. Cumming, Ann Arbor.
45. Milk Charities, With Special Reference to Work Done in Detroit, R. S. Rowland, Detroit.
46. Bacterial Associations in Milk, C. E. Marshall, Lansing.
47. Isolation as a Preventive Measure, G. L. Kiefer, Detroit.
48. The Value of Meat Inspection in the Prevention of Disease, E. H. Hayward, Detroit.
49. The Action of Pneumococcus Germ Substance and Some Split Products Obtained Therefrom, J. F. Munson, Ann Arbor.
50. Sweet Loppering of Milk, L. D. Bushnell, Lansing.
51. Yeast Flavor of Milk, L. D. Bushnell, Lansing.
52. Association of P. radicicola (alfalfa) With Some Soil Bacteria, W. G. Sackett, Lansing.
53. The Value of the Leucocyte Count in Disease, Joseph Sill, Detroit.
54. Immunity With the Split Products of the Colon and Typhoid Bacilli, V. C. Vaughan, Jr., Detroit.
55. The Home Care of Tuberculous Patients, V. C. Vaughan, Ann Arbor.
56. The Trypanesomes in Tsetse-Flies and their Relation to the Trypanesomes of Sleeping Sickness and Nagana, F. G. Novy, Ann Arbor.
57. A New Spirochæta in Tsetse-Fly—Glossina palpalis, F. G. Novy, Ann Arbor.
58. Studies on Spirochæta Obermeieri, F. G. Novy and R. E. Knapp, Ann Arbor.
59. The Flagellum Staining of Spirochæta Obermeieri, C. T. Burnett, Ann Arbor.
60. The Testudinata of Michigan, F. N. Notestein, Alma.
61. Snake Notes, H. L. Clark, Cambridge, Mass.
62. The Geographical Distribution of the Garter Snakes, A. G. Ruthven, Ann Arbor.
63. Notes on the Fish of Hillsdale County, Michigan, T. L. Hankinson, Charleston, Ill.
64. On the Breeding Habits of Pimephales notatus, Jacob Reighard and Cora D. Reeves, Ann Arbor.
65. A New Ichthymyzon from Michigan, With an Account of its Habits, Jacob Reighard and F. E. Wood, Ann Arbor.
66. The Differential Characters of the Scales of the Whitefish and Menominee Whitefish, and its Legal Bearing, Jacob Reighard, Ann Arbor.
67. The Assembling of Cecropia Moths, N. A. Harvey, Ypsilanti.
68. Variation in Polygyra Albolabris in Michigan, Bryant Walker, Detroit.

69. The Marine Biological Station of the Carnegie Institution at Tortugas, Florida, Jacob Reighard, Ann Arbor.
70. Notes on the Habits of Blarina, A. Franklin Shull, Ann Arbor.
71. Notes on the Embryology of Cryptobranchus, B. G. Smith, Ann Arbor.
72. Bird Dissemination of Juniperus, Frank J. Phillips, Ann Arbor.
73. An Ecological Study of the Birds of the Ypsilanti Bayou, Max M. Peet, Ypsilanti.
74. Twenty-five Years of Bird Migration at Ann Arbor, Norman A. Wood, Ann Arbor.
75. The Bird Life of Ann Arbor, Michigan, and Vicinity, Norman A. Wood, Ann Arbor.
76. Notes on the Birds of the Michigan Forestry Reserve, E. H. Frothingham, Ann Arbor.
77. A Topographical Study of the Birds of the "Overflow," at Ann Arbor, Michigan, R. A. Brown, Kalamazoo.
78. An Ecological Survey of Isle Royal, Lake Superior, Chas. C. Adams, Ann Arbor.
79. The Ecological Distribution of the Birds on Isle Royal, Otto McCreery, Ann Arbor.
80. The Fall Migration of Birds on Isle Royal, Max M. Peet, Ypsilanti.
81. Laboratory Work in Biology as Related to Filed Work, J. G. Needham, Lake Forest College, Ill.
82. Laboratory Work in Biology: Nature, Conduct and Value, Louis Murbach, Central High School, Detroit.
83. Laboratory Work in Physiography as Related to Field Work, M. S. W. Jefferson, State Normal College, Ypsilanti.
84. Laboratory Work in Geography, L. H. Wood, Western State Normal, Kalamazoo.

FACT AND FANCY IN BIRD MIGRATION.

WALTER B. BARROWS.

In 1896 Alfred Newton, probably the most scholarly living ornithologist of Great Britain, if not of all Europe, said of bird migration proper: "We are here brought face to face with the greatest mystery which the whole animal kingdom presents—a mystery which attracted the attention of the earliest writers, and can in its chief point be no more explained by the modern man of science than by the simple minded savage or the poet or prophet of antiquity. The flow and ebb of the mighty feathered wave has been sung by poets and reasoned of by philosophers, has given rise to proverbs and entered into popular superstitions, and yet we may say of it still that 'our ignorance is immense.'"

Ten years has added much to the total of our knowledge of birds, yet the gain in that time has come also through subtraction, for we have been compelled to unlearn much that was once considered fixed and sure. The attempt today to sift the known from the unknown in the matter of bird migration is a task of such gigantic proportions that the busy scientist may well hesitate before the undertaking.

We read how tiny and defenceless birds fly thousands of miles at lightning speed through the blackest of nights, yet, guided by some mysterious power, they cross deserts, mountains and even oceans with tireless wing and unerring instinct, arriving presently at the exact spot intended, without loss of time or prestige. Here in a land of peace and plenty they bask in the sunshine, renew their strength and perhaps their travel-worn plumage, and then as the vernal equinox approaches, in obedience to some mysterious inner voice—some pressing, resistless, yet seductive impulse, they break away again for another mad rush through the trackless air toward the land of their birth, where perhaps the nest which cradled them still swings from the bough where it has defied the winter's storm.

No doubt many species make long journeys safely and rapidly, but we now know that a heavy percentage of loss of life goes with every such movement. Undoubtedly certain individual birds find their way back to their birth place after a trip of hundreds of miles and an absence of many months; but it is more than likely that where one individual succeeds in doing this many more fail. Thanks to patient investigation and careful exploration we now know pretty accurately where most of our migrants spend their winters, and we have much reliable information as to the general routes by which some of them go and return, and even the approximate time occupied by the *species* in making the trip, but no sane man pretends to say how long it takes any individual bird to travel from the Gulf of Mexico to Lake Winnipeg,—or even from the Ohio River to the Saginaw Valley.

Formerly well-known scientific men spoke rather confidently of certain birds as migrating only by day and of others which journeyed only at night; possibly there may be a few species which can still be placed in one or the other category, but the number is dwindling every year. The old reasoning,—that because a robin with two white wing-feathers had nested for three consecutive summers in the same tree, therefore all robins regularly return to the places of their birth; or that because certain sparrows and warblers were killed by flying against lighthouses, therefore these kinds migrated only at night; such reasoning—if it can be so called—has given place largely to better logic and the student of today is beginning to demand absolute proof of many of the statements which were accepted as established facts fifty years ago.

A writer of repute as late as the eighteenth century, soberly advanced the hypothesis that when birds disappeared at the approach of winter they took refuge on the moon; and he even estimated the time necessary to reach that haven, and suggested the possibility of smaller intervening satellites as islands on which the weary songsters might rest before completing their trip! Those who scouted this theory suggested various more or less absurd substitutes, and even during the nineteenth century many good people firmly believed that some swallows plunged into lakes and buried themselves in the mud at the approach of cold weather, while other species—particularly the chimney swifts, gathered in multitudes in hollow trees or caverns in the rocks, there to lie torpid until wakened to life by the warmth of returning spring. Nor was there any lack of evidence in support of this theory of hibernation.

In 1878 Dr. Elliott Coues, one of the most brilliant and gifted ornithologists that America has produced, and a good physician as well, devoted five pages of his *Birds of the Colorado Valley* to the possible hibernation of swallows, giving references to upwards of twenty-five papers on this subject and reviewing the evidence with his customary keenness and impartiality. In conclusion he said in part: "The thing is physically and physiologically feasible; it is in strict analogy with observed phenomena in the cases of many other animals; it is not more marvelous than catalepsy, trance, and several other conditions of life the rationale of which is still obscure. Finally, it is attested by the most positive, direct and explicit testimony of eye-witnesses, whose veracity is unimpeached, whose competency is unchallenged, and who, being neither knaves nor dupes, have reiterated the evidence for a period of several centuries. . . . *I* have never seen anything of the sort, nor have I ever known one who had seen it; consequently I know nothing of the case but what I have read about it. But I have no means of refuting the evidence and consequently cannot refuse to recognize its validity. . . . For the rest I may add that I will not ignore, do not deny, and cannot vouch for the statements of authors."* Thus the late Dr. Coues. As an additional bit of evidence in support of the possibility of bird hibernation I would add that a single living chimney swift (*Chaetura pelagica*) came down a chimney and into an office in Ottawa, Canada, the first week in February, 1883. This bird was caught and examined by Mr. Whiteaves, Paleontologist and Zoologist to the Geological Survey of Canada, in whose office it appeared, and it lived several days after capture.

* Birds of Colo. Valley, pp. 375 and 381.

Possibly it is significant to note in this connection that the Chimney Swift is one of the few birds whose winter quarters are as complete a mystery now as they were 100 years ago. Yet we know with considerable accuracy the winter resorts of the great majority of our migratory birds, and each season gives us some additional facts as to the routes by which they go and return.

Out of a total of about 300 species of birds known to occur in the state of Michigan, less than one-fourth are found in winter, and of the 100 or more species of common birds which may be found at any place in the state in June barely a score can be seen in January.

Before attempting to probe any of the deeper mysteries of migration let us consider a few typical examples of our bird population:

During winter the Crow is rarely seen in central Michigan, and except for a few individuals haunting the shores of the Great Lakes, none are seen north of the latitude of Lansing much before the end of February or first of March. About that time, however, small bands of Crows appear everywhere, or single individuals are seen winging their way laboriously northward in spite of high winds or low temperature. Their numbers slowly increase; days there are when their hoarse notes fall from above us all day long, and sometimes toward night great companies, numbering many hundreds or even thousands, gather at some favorite rendezvous to rest and sleep before pushing further north on the morrow.

This tide of sable voyagers rolls northward all through March and most of April, and the superficial observer may not notice that here and there Crows are flying back and forth in pairs, collecting nesting materials, even brooding their eggs, while thousands of their kindred are still pushing on toward the north. Through the late spring and early summer we see crows mainly in pairs or singly; later in little family parties of six or eight, or neighborhood groups of twenty or thirty, and by September flocks of several hundred gather at nightfall to roost in company, scattering during the day to forage in smaller bands or singly. These evening gatherings increase in size and enthusiasm during September or early October, and sooner or later, with numbers augmented to perhaps a thousand, they start southward some fair October day, travelling in a more or less compact body, and at an elevation sufficient to protect them from ordinary firearms, yet near enough to the surface to see and be seen easily.

Investigation warrants the statement that such companies may travel steadily southward for six or eight, or possibly ten, consecutive hours, when they stop to feed, rest and sleep, and a large part of them to move southward again on the morrow if the conditions are favorable. In this way, before the first of November, more than 95 per cent of all the crows which were reared north of the 42d parallel have removed entirely from that area and are congregated in a belt of country perhaps 150 or 200 miles in width, its center being an approximately east and west line running through Baltimore, Cincinnati, St. Louis and Kansas City. Part, perhaps all, the crows native to this east and west belt have meanwhile moved farther south, and have joined the great colonies wintering in Florida, along the Gulf coast, and in Texas.

The northward movement in spring appears to begin with the birds

which have wintered farthest south, but before the first of March the vanguard has pushed into the deserted country north of the 42d parallel and our spring migration has begun. The Crow is a good example of what we may call our summer residents, or summer visitors, though in the southermost counties he may properly be called a permanent resident, and from most of the State he is absent only about one-third of the year.

Perhaps a better example of summer resident is found in the Purple Martin which usually arrives in southern Michigan from the 1st to the 20th of April, nests during May and June, and again moves out of the State before the middle of September, thus spending only five of the twelve months with us. In 1884 the northward movement of these birds was noted from the time they entered the Mississippi Valley, the last of February, until a few arrived at Oak Point, Manitoba, on May 23d. The distance from New Orleans to Oak Point is about 1,440 miles and apparently about ninety days was consumed in making the trip; an average of but sixteen miles a day. However, Prof. W. W. Cooke, who collected the data, was convinced that the forward movement was confined to twelve days (or rather nights), which would make the average about 120 miles per night for the twelve nights of travel.*

This is a bird of such swift and powerful flight that it is perfectly possible for it to speed northward 150 or 200 miles with a warm southerly wind and yet retrace its course the next day in case the weather becomes inhospitable. It seems reluctant to retreat, however, and too frequently the early Martins which are caught by severe cold weather die from starvation. Their food consists almost entirely of insects caught on the wing, and when the temperature drops anywhere near the freezing point very few insects continue to fly. A few benumbed stone flies may be picked from twigs and grass-tips, but not enough to supply heat and strength for these muscular and active birds. The Martin spends the winter entirely south of the United States, some lingering in Mexico and the West Indies, but more pushing far south into Central or even South America.

Among the last birds to reach us in the spring is the Nighthawk, which is rarely seen in any part of the state before the second week in May, and often does not arrive until after the 20th. Fifty years ago, when weather prophets were held in greater esteem than now, the appearance of the Nighthawk was considered a sure sign that there would be no more cold weather. In a general way this may still be true, for it lives entirely on insects which are taken on the wing, and cold weather by preventing insect flight would bring starvation to the Nighthawk. But we know now that no bird is infallible as a weather forecaster, and doubtless each spring thousands of Nighthawks and countless numbers of other insect-eaters perish from starvation as the penalty of pushing north too recklessly. In August and September they pass south again, commonly in large straggling flocks, and by the last week in September all have disappeared from Michigan. A little later they pass out of the United States, visiting the West Indies, Central America and Brazil; and not a few winter far south of the Amazon Valley on the plains of Paraguay, Argentina and Patagonia. Probably

* Birds of the Mississippi Valley, pp. 224-5.

this species remains with us as short a time as any of our summer residents, just long enough to rear its young and get them safely away.

Again we have birds like the Longspurs, the Pipits, Rusty Grackles, and White-crowned Sparrows, Yellowlegs and Ring-neck Plover, Canada Geese, and many ducks, which are strictly birds of passage, or what we prefer to call *transients*, seen only for a few days or weeks in spring as they pass from their winter quarters in the south to their nesting grounds beyond our northern confines, and again for a few days in fall on their return journey accompanied by the young just reared. Yet another group of transients, better called winter visitors, should be mentioned which come to us in autumn or winter from the north and after spending a longer or shorter time with us again withdraw polewards; such are the Snowy Owl, Great Northern Shrike, the Pine Grosbeak and two kinds of Crossbills, together with Redpolls, Snow Buntings, and the much less common Evening Grosbeak and Bohemian Waxwing.

Thus we have four groups of birds, viz.:

1st. Residents or Permanent Residents, with us all the year.
2d. Summer Residents or Summer Visitors (Breeders).
3d. Transients or Birds of Passage.
4th. Winter Visitors or Winter Residents.

Not a few of our common birds are residents in one part of the State and only summer visitors or even transients in another. For example, the Snowbird or Junco and the White-throated Sparrow are transients in the southern half of the State, but summer residents in the northern half; while the Meadowlark and Mourning Dove are only summer visitors in most of the state, but permanent residents in the southernmost counties. For present purposes we may almost disregard the so-called residents or permanent residents, merely remarking that although several species, including woodpeckers, chickadees, creepers, grouse and owls, may be well represented throughout the year in any given locality, we have little proof that the individuals representing these species are the same, and there is every reason to believe that, with a few exceptions, every species of North American bird is more or less migratory in some part of its range. Apparently the Ruffed Grouse and the Prairie Chicken are stationary in Michigan wherever found, yet we know positively that in Minnesota, Iowa and other trans-Mississippi states this last named species makes a well-marked though not very extensive southward migration in autumn, returning northward, however, so gradually and quietly that it attracts little attention.

As another instance of migration in the grouse family, and a most interesting and extraordinary one, I may mention the fact that in eastern Oregon, Richardson's Grouse has its true home among the coniferous forests of the higher mountains from 4,000 to 8,000 feet above sea-level, yet each year in March the greater part of these grouse migrate southward across the Powder River to the sage brush plains and willow thickets of the lower and warmer country, where they nest, old and young returning northward during July and August to the spruce and pine forests of the lofty mountain ranges.*

We may study the main features of migration to best advantage, how-

* A. W. Anthony, Auk, XX, 1903, pp. 24-27.

ever, among those species in which the whole body of individuals swings northward and southward periodically and for long distances, at least 20° to 25° of latitude or 1,200 to 1,500 miles. Among these are representatives of the most diverse orders and families with many peculiar and exceptional cases, yet much general agreement as to the main facts.

Some go openly, in immense flocks, by day and in fair weather, as the swallows, sandpipers and crows; others, like the cuckoos, flycatchers and rails, are commonly believed to go singly and at night, and they drop away so stealthily, even mysteriously, that this supposition seems justified. Many waterbirds, geese, ducks and others, seem to wait for storms of wind or rain and to delight in making their long flights in or just before tempestuous weather.

One of the older and seemingly well-grounded beliefs was that many of the smaller and presumably weaker migrants travelled entirely at night, partly to avoid the attacks of hawks and partly that they might rest and feed by day. The fact that multitudes of such birds do travel at night is undeniable, and perhaps the most marvelous demonstration of this is the discovery (first announced in October, 1880, by W. E. D. Scott) that this migration could be watched easily with a telescope trained on the face of the moon while within a few hours of the horizon. Yet the fact seems to have been very generally overlooked that night flying does not preclude day-flying, and that millions of small birds might pass over our heads at midday and in fair weather, and yet be just as invisible as at midnight, provided they flew at the heights claimed for the nocturnal migrants. Similarly, the fact that birds appear by thousands about lighthouses and electric lights during cloudy and foggy nights carries not the slightest proof that the same species do not travel just as freely by day. As a matter of fact we know that almost all the species killed at lighthouses do make long flights by day under favorable conditions, and an examination of all the accessible evidence leads me to assert that most birds do not fly at night to avoid enemies or escape observation, but merely to take advantage of favorable conditions as yet but partially understood. Telescopic observations at night have shown many small birds flying at heights of from one to three miles, and even at a height of a mile most of these same birds would be entirely invisible to the unaided eye in a clear sky at noon. Moreover, telescopic observations by day—the telescope trained on the sun—have shown in at least two cases birds flying at great heights, far above the reach of our unaided eyesight, and in one of these cases the birds were migrating southward in enormous numbers, the observer stating that "after watching for ten minutes there was no diminution." This was at Shere, Guilford, England, at 3 p. m., on September 30, 1894.*

From the above telescopic observation by daylight and from several similar ones at night the impression would be gained that birds when migrating move at great heights, at least from one to three miles above the surface. One excellent authority, Mr. F. M. Chapman, speaking of results from his own telescopic observations, says: "We determined the greatest altitude at which birds migrate to be three miles . . . many, however, fly at lower levels; indeed, it is not improbable that

* R. A. Bray, Nature, Vol. 52, p. 415.

certain species may, with more or less regularity, travel at a given altitude and that this altitude may vary among birds of different families. With little doubt thrushes and warblers travel at a much lower level than do ducks and geese."* This perhaps is a fair example of unwarranted inference and generalization drawn from the meagre data at hand. Different observers of nocturnal migration, using different instruments under similar conditions (that is always against the face of the newly risen moon) have recorded birds migrating at heights estimated all the way from 600 feet to 15,100 feet. and moving at all speeds from nearly stationary up to 134 miles per hour, with an average of sixty-seven miles per hour for small birds of ordinary powers of flight.

I have not the least desire to belittle the discoveries of these pioneer observers, or to cast any reflection on their honesty of purpose or the accuracy of their records, yet I am free to say that until we have very many more observations in corroboration of these I cannot but doubt that any of our birds, large or small, at any height or under any circumstances, attains a speed even approximating 100 miles an hour. In making this statement of course I invite criticism, but I desire neither more nor less than the truth, and no one will welcome additional evidence more heartily than the writer. At a height of little more than three miles the density of the atmosphere is only half that at the sea-level, hence its resistance to the passage of a bird at that height would be lessened one-half. It does *not follow*, however, that therefore a bird at a height of three and one-half miles can fly at double its speed at the surface without increased effort. A moment's thought will show how preposterous is such a claim. The very tenuity of the air, which lessens by one-half the resistance to the forward motion of the bird, must lessen in exactly the same proportion the supporting power of the air and its resistance in the wing-strokes, which alone give the bird headway. We may dismiss as absurd the claim that birds may double their speed by flying in rarified air. It belongs with that class of popular science that told us until recently that bird's bones were hollow and filled with air, thus rendering them more buoyant and materially aiding in their flight. It is well known now that all the air contained in the birds' air-sacs and bones combined does not alter its specific gravity sufficiently to constitute a factor of the slightest importance in flight.

In this connection we might consider some of the equally absurd claims made by Heinrich Gätke in 1895 in his remarkable book, entitled "Heligoland as an Ornithological Observatory." Heligoland is a little island of less than a square mile's area, located in the North Sea or German Ocean, opposite the mouth of the Elbe and about fifteen miles from the mainland. For more than fifty years Herr Gätke lived on this island and studied its bird life, which is of special interest, since it is almost deserted by birds during the summer, but appears to be a resting point or port of call for scores of species and countless thousands of individuals during their migrations. His list of these species, 397 in all, together with the dates of appearance, relative numbers, and the meteorological conditions, is an important contribution to science, but unfortunately he has included statements of an entirely

* Popular Science Monthly, Vol. 45, 1894, p, 510.

different character, inferences, assumptions, and mere guesses in some cases, as to the distances covered by migrating birds, the height at which they fly and the velocity of their flight. He makes the astounding assertion that the Red-spotted Bluethroat, a little bird which breeds mainly in Northern Europe and winters in Africa, migrates from its winter quarters in upper Egypt to its summer home in Scandinavia, *in a single night and by one continuous flight, without rest;* some individuals flying at least 1,600 miles in nine hours, or an average speed of 180 miles an hour, but some of them even continuing this flight to a distance of 2,400 miles, at a rate of 240 miles an hour! This stupendous claim appears to be based on the alleged fact that this species has not been recorded anywhere in numbers in spring between Egypt and Heligoland!

Similarly Gätke states positively that the American Golden Plover migrates in autumn from Labrador to Brazil, over the Atlantic in one uninterrupted flight of 3,000 miles! He further assumes (without explanation) that fifteen hours is the longest time any bird could remain on the wing without food, and hence that the above flight of 3,000 miles is made in fifteen hours, at an average speed of "212 geographical miles an hour"! He does not explain exactly why this speed is 212 miles instead of precisely 200 miles per hour, as we should figure it, but we need not quibble about a paltry dozen miles in the case of birds moving with such meteoric swiftness. Dr. J. A. Allen, in his kindly and impartial review of this book, says in part: "With all its imperfection it is a book of great interest and value. . . . It is also a book that is likely to do much harm, for it is the sensational and inaccurate parts especially that find their way into the current literature of the day, and particularly into magazines and books devoted to the popularization of Natural History."* The truth of this statement has been fully shown during the ten years which have passed, for Gätke's mis-statements on bird migration have been quoted, requoted, distorted and enlarged upon until it can no longer be hoped that the mischief may ever be undone.

After careful search I have been unable to find a single instance in which the speed of any bird has been shown by actual measurement to reach even 100 miles an hour. There are plenty of guesses, a few bold but unsupported assertions, and a number of more or less probable estimates.

The figures furnished by pigeon fanciers give us some idea of the possibilities of the homing pigeon, so often miscalled the "carrier pigeon." These records of course give only the average speeds, but these are certainly suggestive. The greatest velocity of which I find mention is eighty miles an hour, at which rate a homing pigeon is said to have covered 114 miles in 1892. I am unable, however, to verify this statement.† Another, and more likely record, is seventy-one miles an hour for a distance of eighty-two miles, while the average velocities of the winners in a large number of contests do not exceed forty miles an hour. In 1883 the best time made in eighteen races was 208 miles at the rate of fifty-five miles per hour. Over longer distances the velocity is very

* Auk XIII, 153.
† Headley, Structure and Life of Birds, p. 268.

much less, and in the longest flight of which I can find a record, that of a pigeon which flew from Pensacola, Florida, to Fall River, Mass., fifteen and one-half days were consumed in covering the 1,183 miles, the average speed being seventy-six miles per *day*.

In experiments tried with swallows in France it is claimed that one swallow flew 160 English miles in ninety minutes, giving a velocity of 106 miles an hour, but this record is open to serious question.

Audubon estimated the speed of Passenger Pigeons, our own Wild Pigeon, at fifty miles per hour, which is probably within the limit; yet his estimate involved several factors no one of which was absolutely known. He found rice in the crops of pigeons and from its condition "judged" that it had been eaten six hours before. He assumed that the nearest place at which it could have been obtained was in Carolina, 300 to 400 miles distant!

An Albatross marked with its latitude and longitude is said to have been released from a ship in one part of the Pacific Ocean and captured twelve days later by another vessel at a distance of 3,150 miles. Even if true, this only required the bird to travel 262 miles per day, less than eleven miles per hour.

Wild geese, and especially wild ducks, have been credited with a speed of nearly 100 miles an hour, yet in two cases where it was possible to measure the speed of flocks passing a given point, it was found that the geese flew at the rate of but 44.3 miles per hour, and the ducks at approximately forty-eight miles per hour, and in neither case did the height exceed 1,000 feet. These measurements were made at the Blue Hill Meteorological Observatory at Milton, Mass., by trained observers with the instruments used daily in determining the velocity of clouds.* In 1893 Dr. Hubert L. Clark (one of our own members) noted two buffle-head ducks flying along the Potomac River parallel with a train on which he was a passenger. The train was found to have a speed of about thirty-seven miles an hour, and the ducks were unable to keep up with it!

Herr Gätke's statement that the American Golden Plover flies at the rate of over 200 miles an hour is based on data which he misunderstood or misrepresented. There is absolutely no proof that any of the plover pass from Labrador to Brazil at one flight, nor do we know even approximately the time taken for the trip as performed. Presumably they do make flights of 300 or 400 miles without rest, since they are often seen passing Bermuda without resting, and have probably flown continuously since leaving the North American coast; yet *should* they tire there is no reason whatever why they should not rest upon the sea at any time except during storm, and it is well known that in case of heavy storms thousands of them do alight on the Massachusetts coast as well as on Bermuda, while the species lingers regularly for weeks on some of the West Indian Islands.

Most shore birds take to the water readily and swim buoyantly and easily. Flocks of sandpipers have been seen to alight in the water when far out of sight of land; and yet there can be no doubt that many of our land birds, which could not rest on the water at all, often fly 300 or 400 miles across the water without serious fatigue. We have no

* Clayton, Science N. Ser. V. pp. 26, 585-586.

means of knowing whether such journeys (in the case of land birds) are undertaken volutarily or not, but doubtless in very many cases the birds are swept off the coast by heavy winds and comparatively few of their numbers ever reach a safe refuge. It is a significant fact, as pointed out by Mr. Henshaw many years ago,* that when land birds come aboard vessels at any distance from land they invariably die from exhaustion, no matter what care be taken of them.

Doubtless one reason why migrating birds fly at great heights in fair weather is because it is easier. So long as the breeze is in the right direction they utilize it to the full, but if compelled by circumstances to face a wind they find it far easier to fly near to the surface where they can take advantage of such eddies and counter currents as may appear, and where at all events the velocity of the wind will be less than at higher levels. Another and possibly the strongest reason for flying at great elevations lies in the fact that the view thus obtained is of paramount importance to the migrant. At a height of two miles a bird in clear weather commands a view of an area nearly 200 miles in diameter, so that under favorable conditions, it might cross any of our great lakes, or even reach South America by way of the West Indies without ever being out of sight of land. Should the weather conditions become unfavorable, however, after a start has been made, the little travellers must make the best of a bad matter and meet the emergency as best they may. Were they gifted with the extraordinary powers popularly assigned them they would rarely or never be caught and overwhelmed as they so often are. Were they able to fly even seventy-five miles an hour, they could flit to safety on the first appearance of bad weather, well knowing that a few hours of clear weather would enable them to recover all the ground lost. In spite of the general belief that birds are able to foretell meteorological changes and forestall dangerous storms, the weather is very largely responsible for the terrible destruction which thins their ranks and brings death to so large a proportion of our bird population every year.

It is clear that, on the average, as many birds die each year as are born, else the individuals of any species would increase in numbers year by year until they became intolerably abundant. As it is, some species increase for a time and then their numbers fall away again. There is a constant oscillation in numbers with occasional decreases to such a point that recovery becomes impossible, and the species becomes extinct. Ordinary minor oscillations may occupy but a very few years, but more often apparently one or more decades may be required for the completion of such a cycle. Several well-marked examples of such cycles have fallen under my own observation. I saw the Passenger Pigeon pass through one of its minor fluctuations apparently culminating between 1870 and 1875, after which time it rapidly declined until now it trembles on the utmost verge of extinction.

In the winter of 1894-95 most unfavorable weather conditions in the south nearly annihilated the Bluebird and so far reduced the number of Robins reared in this section of the north that their normal numbers were not regained for at least six years.

We have not time to go into the causes of mortality among birds,

* Bull. Nutt. Orn. Club, VI. 194.

but it is evident that a very large percentage of the young and inexperienced birds which start south in autumn never return to their birth place—probably having perished from the dangers of the trip. As a rule the southward journey is made—or at least might be made—with comparative safety. There is no need of great haste, food is abundant and the travellers are moving always toward regions of increasing warmth and superabundant food. On the northward trip on the contrary, the birds often are leaving safety and abundance behind them, are pushing continually into colder and hungrier regions, and are likely at any moment to be met with climatic conditions that test their strength and endurance to the utmost and often exact the extreme penalty of death. Take an instance or two in illustration of this statement. April 2, 1881, Mr. A. M. Frazar was a passenger on a sailing vessel about thirty miles off the mouths of the Mississippi, with a moderate east wind blowing and no land birds in sight. Suddenly, about noon, the wind changed to the north and increased to a gale, and within an hour birds of many species appeared, singly and in small flocks, having come down from far overhead to escape the force of the wind. All were flying toward the land, directly to windward, and in the teeth of the growing storm. "Within a few hours," says Mr. Frazar, "it had become a serious matter with them, as they could make scarcely any progress. As long as they were in the trough of the sea the wind had little effect on them, but as soon as they reached the crest of a wave it would catch them up and in an instant they were blown hundreds of yards back or else into the water and drowned. . . . It was sad indeed to see them struggling along by the side of the vessel in trying to pass ahead of her, for as soon as they were clear of the bows they were invariably blown back into the water and drowned. Most of those which came aboard (considerably over a hundred) were washed into the sea again."* Twenty-three different species were identified, including warblers, finches, flycatchers and a single swallow, hawk, dove and turnstone. Probably these were all migrants which had almost crossed the Gulf of Mexico from the Peninsula of Yucatan, only to be swallowed up by the angry sea when almost within sight of their goal.

Another observer describes the disaster caused to birds on Lake Michigan by a violent storm in September, 1879, as follows: "The eastern shore of Lake Michigan was strewn with dead birds. I took pains to count those on a certain number of yards, and estimated that if the eastern shore was alike through all its length, over a half a million birds were lying dead on that side of the lake alone. It is more than likely that nearly as many more were on the west. It was a strange and pitiful sight." There were wrens, creepers, kinglets, robins, kingbirds, warblers, sparrows, finches, woodpeckers, and even a few blue jays and kingfishers. Here apparently temperature played no part, but wind and heavy rain baffled the little migrants whichever way they turned, and finally beat them down into the relentless waves.

One more example of such destruction will suffice: February 12, 1899, at Mt. Pleasant, South Carolina, on the coast, sleet began falling, and the next day the snow was four or five inches deep, and the temperature 14° above zero, dropping to but 6° above zero on Thurs-

* Bull. Nutt. Orn. Club, VI, 250-251.

day the 14th. In the words of the narrator, Arthur T. Wayne, "The destruction of bird life caused by this cold wave can scarcely be conceived. To say that Fox Sparrows and Snowbirds were frozen to death by the millions is a conservative statement. Thousands tarried in my yard all day long and swarmed in the piazza, fowl-yard, and every place that would afford protection. . . . When they were benumbed by the cold Boat-tailed Grackles and Red-winged Blackbirds would peck them at the base of the skull, killing them and eating them. The stronger Fox Sparrows would also eat their dead companions. It was a most pathetic sight. I caught quantities of Fox Sparrows, Grass Finches, Snowbirds and Chipping Sparrows and put them into a large cage which I brought into the house and placed before a large fire with the hope of saving them from destruction, but despite this they all died. . . . The Woodcock arrived in countless thousands. . . . They were everywhere and were completely bewildered. Tens of thousands were killed by would-be sportsmen and thousands were frozen to death. The great majority were so emaciated that they were practically feathers and of course were unable to stand the cold. One man killed 200 pairs in a few hours." Mr. Wayne names sixteen species of birds that were killed in large numbers by this cold wave.*

We have not time to discuss the alleged power of birds to divine coming storms, nor can we enter into a consideration of such instincts as should save them from such disasters as those just described. I have tried to show already that they possess no such extraordinary powers of flight as are ascribed to them by popular writers, and had we the time, it might be shown, I believe, that at least for a very large part of their migratory flight they do not follow fixed paths, nor do they retrace their footsteps—or better, wing-beats—through memory. That certain great natural highways exist, I have no doubt, but certainly part of the throngs of birds which use them do so not because they have ever used them before, or even because their ancestors used them, but because the same forces which led to their use then are still operative and because these routes are the easiest and best paths to the regions desired.

It goes without saying that the motives for migration,—the cause or causes, are ever at work, but whether we understand these or not, the great facts of migration are always before us and the ways in which it is accomplished demand explanation. Inherited habit, instinct, phenomenal eye-sight, remarkable memory, amazingly developed power of orientation, all these have their part in the scheme; and I am willing to give the birds credit for helping each other, the older for guiding the younger, and the younger for submitting to be led. Yet no one of these factors, nor all combined, will fully explain such facts as that the great bulk of American Golden Plover reared in northwestern Arctic America, move southeastward to Labrador, southward over the Atlantic or along the coast to Brazil and finally to the Pampas and plains of Argentina and Patagonia, 6,000 or 7,000 miles from their birthplace, and that eventually those which live resort again to Northwestern America to nest without ever passing in sight of a single region which they visited on their southward trip. This seemingly inexplicable route

*Auk. XVI, 1899, pp. 196-198.

has been fully explained recently by Mr. Austin H. Clark,* on the theory (well supported by observation) that these and many other birds while migrating prefer to fly with what sailors call a "beam-wind," that is they fly at right angles to the course of the wind, which naturally causes them to make more or less lee-way according to the strength of the wind, but in no way interferes with forward progress—in fact greatly helps the bird by giving it a steady support. According to this theory birds coming north in the spring would move northeastward when the wind was from the northwest, and northwestward if the wind were from the northeast, while they would make a direct northward trip only on an east or a west wind. Since the winds blow alternately from different directions, any deviation to east or west would tend to be corrected in any extended migration, and in this way on the average the bird would have as good a chance of reaching his goal as if he attempted to proceed in a direct line, in spite of head winds or deflecting winds of any kind. Naturally a migrant would alight, if possible, rather than be blown backward on his course, and naturally also if the wind threatened to carry him out to sea he would alight or coast alongshore as the case might be. Precisely this condition of affairs seems to arise frequently in the case of hawk migration along the southern New England coast, where the birds, flying at right angles to the prevailing southwesterly winds are gradually collected along the sea-shore and follow the coast southward to New Jersey and the Carolinas.

It is also certain that not enough attention has been given to the influence of the rising currents of warm air which are utilized constantly by soaring birds and doubtless by most migrants. Consideration of these subjects, however, would involve a discussion of the mechanics of flight, for which this is not the time.

In conclusion let me urge everyone who aspires to contribute his part to the fund of science that he be scrupulously careful in observation and record of every fact, and that he remember always that a theory is of use just so long as it serves as a point on which facts can be securely hung; when the point becomes too small or the hook points the wrong way it is time to find another place for the facts, while the theory may well be consigned to the waste basket.

Agricultural College, Mich., March, 1906.

* Auk, XXII, 1905, pp. 134-140.

UNREPORTED MICHIGAN FUNGI FROM PETOSKEY, DETROIT AND ANN ARBOR FOR 1905.

C. H. KAUFFMAN.

The following list of fungi were collected chiefly around Petoskey, Emmet County, by the writer, and around Detroit by the Detroit Mycological Club. As the data show, the forms from northern Michigan were obtained mostly in a primeval forest, just back of the Bay View resort, and belonging to that Association. This forest covers over one hundred acres and has within its limits a low area of hemlock and yellow birch, and an ancient cedar swamp; a part of it rises rather abruptly some seventy-five feet or more to form an extensive terrace covered with hard maple. A great variety of habitats are thus formed from a mycological point of view, and the yield of unreported plants has been correspondingly large. The ground is covered in places by the prostrate, mossy trunks of mighty hemlocks and forest debris, or carpeted by the clean mass of magnificent mosses beneath the cedars, while the maple area is either covered with a dense undergrowth of young saplings or with a tangle of rottting maple trunks.

The Detroit Mycological Club through its energetic president, Dr. O. E. Fischer, have added to our known flora in the list below some fifty species. Their collecting was mainly done in the neighborhood of Detroit, Wayne County, in its parks, on Grosse Isle, and especially in a rich oak woods abont seven miles from the city. I take this opportunity to thank Dr. Fischer and the Club for the large amount of material sent me during the past season.

Thanks are also due Prof. G. F. Atkinson and Dr. C. H. Peck for their valuable assistance in diagnosing the Basidiomycetes sent them, and to Dr. E. J. Durand for similar services among the Ascomycetes.

In addition to the two groups mentioned, a list of the Phycomycetes of Michigan will be included. Most of this list comes from the University herbarium or was collected or found in cultures in the laboratory. As in the preceding paper,* the arrangement of groups and families will be that of *Engler and Prantl Pflanzen-familien;* in a few cases, however, well-known generic names are retained for the sake of convenience.

It is to be hoped that the work will be continued from year to year and that more clubs throughout the State will take an active part.

(Abbreviations: C. H. K.=C. H. Kauffman; L. N. J.=L. N. Johnson; D. M. C.=The Detroit Mycological Club; Pk=Peck; Atk=Atkinson.)

* See 7th Report, Mich. Acad of Scienc.

PHYCOMYCETES.

Synchytriaceae.

Synchytrium anemones (D. C.) Wor. On anemone nemorosa L. May, fide Spalding.

Synchytrium decipiens Farlow. On Amphicarpaea monoica Nutt. July, fide C. H. K.

Synchytrium pluriannulatum B. & C. On Sanicula Marylandica L. July-Aug., fide Spalding.

Rhizidiaceae.

Harpochytrium hedenii Wille. On Spirogyra sp. fide C. H. K.

Cladochytriaceae.

Physoderma menyanthis DeBary. On Menyanthes trifoliata L. June, fide L. N. J.

Saprolegniaceae.

Achlya polyandra Hildb. From Cladophora, Huron River. Nov., fide C. H. K.

Achlya prolifera (Nees ab E.) DeBary. With mosses, in ditch, Chelsea. Nov., fide C. H. K.

Achlya Treleaseana (Humphrey). Among Cladophora. Huron river. Nov. The sporanges emptied in the manner of Achlya; in every other respect it agreed with Saprolegnia Treleaseana Humphrey, and is no doubt the same plant. Only one sporange had been seen by Humphrey. fide C. H. K.

Aphanomyces laevis DeBary. With Oedogenium collected near Ann Arbor. fide C. H. K.

Saprolegnia hypogyna Pringsh. Among water plants, Cedar Lake, Nov., fide C. H. K.

Saprolegnia mixta. DeBary. With Cladophora, Huron River. Nov., fide C. H. K.

Albuginaceae.

Cystopus bliti DeBary. On Amaranthus retroflexus L. Mich. Agr. College, fide Beal.

Cystopus candidus (P) Lev. On Brassica nigra Koch.; Capsella bursa-pastoris, Moench; and Dentaria diphylla L. May-Oct., fide Wheeler & Spalding.

Cystopus portulacae (D. C.) Lev. On Portulaca oleracea L. Ann Arbor, fide Spalding.

Cystopus tragopogonis (Pers.) Schroet. On Ambrosia artemesiaefolia L. fide Merrow.

Peronosporaceae.

Bremia Lactucae Regd. On Lactuca leucophorum D. C. June-Aug., fide Spalding.

Peronospora alta Fkl. On Plantago major L. June-Aug., Ann Arbor, etc., fide Spalding.

Peronospora corydalis DeBary. On Dicentra Canadensis D. C., May 12, fide Merrow.

Peronospora effusa (Grev.) Rabh. On Chenopodium album L. June, fide Spalding.

Peronospora Ficariae Tul. On Ranunculus repens L. et R. fascicularis Muhl. Ann Arbor, May, fide Spalding.

Peronospora myosotidis DeBary. On Myosotis verna L. Ann Arbor, May-June, fide L. N. J.

Peronospora parasitica (P.) DeBary. On Dentaria laciniata Muhl. et Lepidium Virginicum L. May-June, fide Merrow.

Peronospora potentillae DeBary. On Potentilla Norwegica L. Ann Arbor, May, fide Spalding.

Phytophthora infestans (M.) DeBary. On Solanum tuberosum.

Plasmopora Halstedii (Farl.) Berl. On Eupatorium purpureum, L., etc. July-Sept., fide Spalding.

Plasmopora pygmaea (Unger) Schroet. On Anemone Pennsylvanica L. et A. nemorosa L. May 13-18, fide Spalding.

Plasmopora viticola (B. C.) Berl. & Detoni. On cult. Vitis sp. Mich. Agr. College, fide Wheeler & Beal.

Plasmopora obducens Schroet. On Impatiens fulva Muhl. May 13.

Plasmopora nivea (Ung.) Schroet. var. Geranii. Farlow. On Geranium sp., fide Farlow.

Mucoraceae.

Mucor ambiguum Vuill. On mummied plums. Ann Arbor, Mar., fide Pollock.

Mucor mucedo Linné. Laboratory cultures. Ann Arbor, fide C. H. K.

Mucor mucilagineus Bref. Probably a variety of the type from which it differs slightly. On decaying fungi. Summer, fide C. H. K.

Mucor spinosus Van Tiegh. On rat dung. Holland, Mich., fide A. J. Pieters.

Rhizopus nigricans Ehr. On cultures in Laboratory.

Sporodinia grandis. Lk. On decaying fungi. Summer, fide C. H. K., etc.

Thamnidium elegans Lk. On rat dung. Dec., fide L. N. J.

Entomophthoraceae.

Empusa muscae (Fr.) Cohn. On house flies. Ann Arbor, fide C. H. K.

Empusa sphaerosperma (Fres.) Thax. On clover weevil. Ann Arbor, May 10, fide L. N. J.

ASCOMYCETES.

Geoglossaceae.

Geoglossum ophioglossides (Linné) Sacc.=(G. glabrum Pers.) Ground in hemlock woods. Emmet County, July 28,* fide Durand.

Geoglossum fallax Durand (in ed.). Ground in hemlock woods. Emmet County, July, fide Durand.

Geoglossum hirsutum Pers.—(Trichoglossum americanum (Cke.) Durand (in ed.). Ground, hemlock woods. Emmet County, Sept. 4, fide Durand.

Spathularia velutipes. Cke et Farlow. Ground, in hemlock woods. Emmet County, Aug., fide Durand.

Helvellaceae.

Cudonia circinans. (Pers.) Fr. In hemlock swamp. Emmet County, Aug. 4, fide Durand.

* The specific dates refer to the first collection of that particular fungus during the season. Often this is approximately the earliest date, rarely the fungus may have been common before.

Helvella atra Konig. On ground, cedar swamp. Emmet County, July 21, fide Durand.

Helvella macropus (Pers.) Karst. Ground hemlock and birch woods. Emmet County, July 21, fide C. H. K.

Leotia lubrica. (Scop.) Pers. Ground, cedar and hemlock swamp. Emmet County, Sept. 7, fide C. H. K.

Leotia stipitata (Bosch.) Schroet. Ground, hemlock woods. Emmet County, Sept. 9, fide Durand.

Pezizaceae.

Aleuria aurantia (Mull.) Rehm. Ground, beech and maple. Emmet County, Sept. 13, fide C. H. K.

Galactinia succosa. Berk. Ground, hemlock woods. Emmet County, July 31, fide C. H. K.

Lachnea aurantiopsis Ell., or near. Emmet County, Sept., fide Durand.

Lachnea erinacea (Schw.) Sacc. Cow dung. Washt. County. Mar., fide Durand.

Lachnea stercorea (Pers.) Gill. On cow dung. Sault Ste. Marie, Aug., fide C. H. K.

Lachnea hemispherica. (Wigg.) Gill. Ground, in hemlock woods. Emmet County, July, fide C. H. K.

Lachnea scutellata Linné. On rotten wood, in woods. Emmet County, July, fide C. H. K.

Peziza griseorosacea Gerard. D. M. C. Ground. Grosse Isle., Sept. 11, fide Pk.

Peziza odorata Pk. D. M. C. In pasture. Oakland County, Aug., fide Pk.

Plectania hirtipes Cke.=(Lachnea hirtipes. Cke. According to Lindau.) On rotten wood. Emmet County, Aug., fide C. H. K.

Ascobolaceae.

Ascobolus stercorarius (Bull.) Schroet. On cow dung. Washt. County, Mar., fide C. H. K.

Helotiaceae.

Helotium epiphyllum. (Pers.) Fr. On rotting leaves. Emmet County, Sept., fide C. H. K.

Sarcoscypha floccosa Schw. On sticks, etc., Oak woods. Washt. County, July 4, fide C. H. K.

Erysibaceae.

Microsphaera symphoricarpi Howe. On leaves of Symphoricarpus vulgaris. Michx. Washt. County, Sept., fide Pollock.

Uncinula flexuosa Pk. On leaves of Aesculus hippocastanum L. Washt. County., Oct., fide Pollock.

BASIDIOMYCETES.

Hymenomycetineae.

Clavariaceae.

Clavaria flava Schaeff. D. M. C. Oak woods on ground. Wayne County, Aug., fide C. H. K.

Clavaria formosa Pers. D. M. C. Oak woods. Wayne County, Aug., fide PK.

Clavaria fragilis Holmsk. Ground, cedar swamp. Emmet County, Aug. 5, fide C. H. K.

Clavaria ligula Fr. On ground under white pine. Emmet County, Sept. 7, fide C. H. K.

Clavaria mucida Pers. On mossy log, in beech and maple woods. Emmet County, Oct. 19, fide C. H. K.

Clavaria pulchra Pk. On ground, hemlock and birch woods. Emmet County, Aug. 25, fide C. H. K.

Clavaria rugosa Bull. On ground, hemlock and birch woods. Emmet County, July-Aug., fide C. H. K.

Clavaria Schaefferi Sacc. On ground, hemlock and birch woods. Emmet County, Sept. 7, fide C. H. K.

Clavaria subtilis. Fr. On ground, hemlock and birch woods. Emmet County, July 26, fide C. H. K.

Lachnocladium semivestitum. B. (Syn.=C. velutina E. & E.) On rotten wood, cedar swamp. July-Sept., fide Atk.

Polyporaceae. (Fleshy.)

Boletinus cavipes Opat. Ground, tamarack swamp. Washt. County, Nov. 11, fide Pollock.

Boletinus paluster Pk. Ground, tamarack swamp. Washt. County, Nov. 6, fide Pollock.

Boletinus grisellus Pk. On sphagnum, tamarack swamp. Oct 16, Washt. County, fide Pk.

Boletus Atkinsoni Pk. D. M. C. et Washt. County. Oak woods. July, fide Pk.

Boletus cyanescens Bull. Very sandy soil. Emmet County, July 31, fide C. H. K.

Boletus affinis var. maculatus Pk. Ground, hemlock woods. Emmet County, Aug. 14, fide C. H. K.

Boletus edulis Bull. Washtenaw County, July 4, fide C. H. K.

Boletus gracilis Pk. Ground, hemlock woods. Emmet County, Aug., fide C. H. K.

Boletus indecisus Britz. D. M. C. Oak woods. Wayne County, July, fide Pk.

Boletus ornatipes Pk. D. M. C. Oak woods. Wayne County, July, fide Pk.

Boletus pallidus Frost. D. M. C. Oak woods. Wayne County, July, fide Pk.

Boletus purpureus Fr. Washtenaw County, July, fide C. H. K.

Boletus punctipes Pk. On ground, hemlock woods, Emmet County, fide C. H. K.

Agaricaceae.

Agaricus cretacellus Atk. On hemlock and birch woods. Emmet County, Sept., fide C. H. K.

Amanita bisporiger Atk. (in ed.). Ground, maple woods. Emmet County, Aug.-Sept., fide C. H. K.

Amanata cothurnata Atk. D. M. C. Ground in oak woods. Wayne County, July, fide C. H. K.

Amanita flavoconia Atk. D. M. C. Oak and maple woods. Wayne and Emmet Counties, July, fide C. H. K.

Amanita mappa Fr. Sandy thickets. Emmet County and Washt. County, Sept. 12, fide C. H. K.

Amanitopsis strangulata (Fr.) Roze. Ground, hemlock and birch woods. July 15, fide C. H. K.

Amanitopsis volvata Pk. D. M. C. Oak woods. Wayne County, Aug. 27, fide Pk.

Bolbitius fragilis (L.) Fr. On ground in wheat field. Washt. County, May 27, fide C. H. K.

Clitocybe Adirondackensis Pk. D. M. C. Oak woods. Oakland County, July, fide Pk.

Clitocybe eccentrica Pk. On rotten wood, hemlock and beech woods. Emmet County, July 15, fide Pk.

Clitocybe ectypoides Pk. On cedar logs. Emmet County, Aug.-Sept., fide C. H. K.

Clitocybe truncicola Pk. D. M. C. On old roots of maple. Oakland County, Sept., fide Pk.

Clitocybe piceina Pk. Washt. County. Aug., fide Pk.

Clitopilus Orcella Bull. D. M. C. Oak woods. Wayne County, Sept. 19, fide C. H. K.

Clitopilus Woodianus Pk. Among leaf mould, oak woods. Washt. County, Sept. 18, fide Atk.

Coprinus sylvaticus Pk. On very rotten wood, hemlock and beech woods. Emmet County, Aug. 27, fide Pk.

Collybia butyracea Bull. Among leaf mould in low woods. Wayne County, Oct. 16, fide C. H. K.

Collybia ligniarius Pk. On old beech logs. Emmet County, Sept. 5, fide C. H. K.

Collybia maculata Alb. & Schw. Ground, in maple woods. Emmet County, July 22, file C. H. K.

Cortinarius armillatus (Alb. et Schw.) Fr. Leaf mould, very rotten wood, stumps, etc., in hemlock woods. Aug. 22, fide C. H. K.

Cortinarius annulatus Pk. D. M. C. Oak woods. Wayne County, Aug. 20, fide C. H. K.

Cortinarius bivelus Fr. Ground, hemlock and balsam swamps. Emmet Co., Sept., fide C. H. K.

Cortinarius bolaris (Pers.) Fr. Ground, cedar swamp. Emmet County, Sept. 5, fide C. H. K.

Cortinarius caerulescens Fr. D. M. C. Ground, oak woods. Wayne County, fide C. H. K.

Cortinarius castenellus Pk. Grassy field, border of woods. Washt. County, Oct. 15, fide C. H. K.

Cortinarius cinnabarinus Fr. Ground, oak woods. Washt. County, July 7, fide C. H. K.

Cortinarius collinitus (Pers.) Fr. Hemlock swamp, on ground. Emmet County, Aug. 22, fide C. H. K.

Cortinarius corrugatus Pk. D. M. C. Ground, woods. Wayne County, Aug. 27, fide C. H. K.

Cortinarius Clintonianus Pk. Ground, in hemlock woods. Emmet County, Sept. 1, fide C. H. K.

Cortinarius croceocaeruleus. (Pers.) Fr. Ground, in hemlock woods. Emmet County, Sept. 9, fide C. H. K.

Cortinarius cylindripes Kauff. On moss, hemlock swamp. Emmet County, Aug. 30, fide C. H. K.

Cortinarius distans Pk. Ground, near beech trees. Washt. County, Sept. 18, fide C. H. K.

Cortinarius deceptivus Kauff. Ground, among debris in hemlock woods. Emmet County, Aug. 22, fide C. H. K.

Cortinarius evernius Fr. Under hemlock trees, swamp. Emmet County, Aug. 7, fide C. H. K.

Cortinarius flavifolius Pk. D. M. C. Oak woods. Wayne County, Aug. 27, fide C. H. K.

Cortinarius fulgens (Alb. et Schw.) Fr. Ground, near beech trees. Washt. County, Sept., fide C. H. K.

Cortinarius glaucopus (Schaeff.) Fr. Ground, oak woods. Washt. County, Sept., fide C. H. K.

Cortinarius lilacinus. Pk. D. M. C. Oak woods. Wayne County, Sept., fide Pk.

Cortinarius multiformis Fr. Leafmold in hemlock woods. Emmet County, Sept. 9, fide C. H. K.

Cortinarius olivaceus Pk. Cedar swamp, among moss. Emmet County and Wayne County, Aug. 20, fide C. H. K.

Cortinarius obliquus Pk. Oak woods. D. M. C. Wayne County, Aug. 20, fide C. H. K.

Cortinarius paleaceus (Weinm.) Fr. Ground, oak woods. Washt. County, Sept. 18, fide C. H. K.

Cortinarius pholideus Fr. On debris in Cedar swamp. Emmet County, Sept. 5, fide C. H. K.

Cortinarius purpurascens Fr. D. M. C. Oak woods. Wayne County, Sept. 19, fide C. H. K.

Cortinarius rubipes sp. nov. (Telamonia.)

Pileus 5-11 cm. broad, convex-campanulate then expanded, *hygrophanous,* watery cinnamon when moist and with a more or less ferruginous umbo or stained ferruginous in places, drying in zones from the umbo outward and becoming paler, pinkish-ochraceous and with innate silky shining fibrils when dry, obtuse, sometimes wavy and irregular, smooth, even, flesh thin except on disk, scissile. Gills 6-15 mm. broad, not crowded, adnate, often with minute hoary fibrils at point of junction with stem, seceding when old, pale cinereous-purplish when young, soon cinnamon, edge even, whitish or concolor. Stem 5-7.5 cm. long, with an oval bulb, above which it is .5-1.5 cm. thick, *bulb deep brick-red* to vermillion shading off to a pellucid, pinkish tinge at the apex of stem, elastic, spongy-stuffed within, outer layer rather tough, smooth except for the fibrillose remains of the thin, evenescent, pale reddish, universal veil. Spores elliptical, 8-9x5 microns, smooth, cinnamon.

Gregarius or caespitose, on the slope of a ravine covered with oak and maples, Ann Arbor, Mich., July 4, 1905.

The stem is attached to roots of Acer saccharinum and Quercus rubrum on which it forms mycorhiza. For full account and figures, see Bot. Gaz. Vol. XLII, 1906.

Cortinarius semisanguineus Fr. Oak woods. Washt. County, July, fide C. H. K.

Cortinarius squamulosus Pk. D. M. C. Ground, oak woods. Wayne County, Aug. 27, fide C. H. K.
Cortinarius sterilis Kauff. Ground, cedar swamp. Emmet County, Sept., fide C. H. K.
Cortinarius subflexipes Pk. On debris of hemlock woods. Emmet County, July 24, fide C. H. K.
Cortinarius torvus nobilis Pk. Ground, hemlock swamp. Sault Ste. Marie, Aug. 22, fide C. H. K.
Cortinarius uliginosus Berk. On sphagnum. Emmet and Washt. Counties, fide C. H. K.
Cortinarius vibratilis Fr. D. M. C. Ground, swampy woods. Wayne County, Aug. 27, fide C. H. K.
Cortinarius umidicola Kauff. D. M. C. Low, swampy woods. Wayne County, Sept., fide C. H. K.
Crepidotus Ralfsii B. & Br. On rotten wood, maple woods. Emmet County, Aug., fide C. H. K.
Crepidotus haerens Pk. On rotten wood. Washt. County, Sept. 17, fide C. H. K.
Deconica coprophila (Bull.) Fr. On horse dung. Washt. County, May 18, fide Pk.
Deconica bullacea (Bull.) Fr. Meadows and pastures. Washt. County, May 18, fide Pk.
Eccilia carneo-grisea B. & Br. Probably a variety, as it differs slightly in spore characters and gills. On ground, cedar swamp. Emmet County.
Entoloma nidorosum Fr. On moss in sphagnum swamp. Emmet County, Sept. 1, fide C. H. K.
Entoloma salmoneum Pk. Ground, hemlock woods. Emmet County, Sept. 13, fide C. H. K.
Entoloma sericellum Fr. Hemlock swamp. Emmet County, Sept. 1, fide Atk.
Flammula spumosa Fr. D. M. C. On rotten wood. Emmet and Wayne counties, Sept. 1, fide C. H. K.
Gomphidius vinicolor Pk. D. M. C. Oak woods. Oakland County, July, fide Pk.
Gomphidius nigricans Pk. Under tamaracks. Washt. County, Oct. 12, fide C. H. K.
Hebeloma album Pk. D. M. C. Pasture, near Rochester. July, fide Pk.
Hypholoma hydrophilum Bull. D. M. C. Base of stumps. Wayne County, fide C. H. K.
Hygrophorus glutinosus Pk. Ground, thickets. Washt. County, Sept 18, fide C. H. K.
Hygrophorus Peckii Atk. Cedar swamp. Emmet County, Aug. 10, fide Pk.
Hygrophorus pratensis (Pers.) Fr. Ground, border of woods. Emmet County, July 13, fide C. H. K.
Hygrophorus pratensis Fr. var. pallida Pk. D. M. C. Grosse Isle, Sept., fide Pk.

Hygrophorus puniceus Fr. Emmet County. On mosses in cedar swamp. Aug. 11, fide C. H. K.

Hygrophorus puniceus Fr. var. flavescens, var. nov. Differs from type in its white gills and citron-yellow stem. On mosses in cedar swamp with the preceding. Emmet County, Aug., fide C. H. K.

Hygrophorus speciosus Pk. Under tamaracks. Washt. County, Nov., fide Pollock.

Inocybe asterospora Quelet. Ground, hemlock and birch woods. Emmet County, July 17, fide Atk.

Inocybe calamistrata Fr. Ground, hemlock woods. Emmet County, Aug. 8, fide Atk.

Inocybe Cookei Bres. Ground, woods. Emmet County, Aug. 18, fide Atk.

Inocybe entomospora Atk. (in ed.) Debris of Cedar swamp. Emmet County, Sept. 5, fide Atk.

Inocybe flocculosa Berk. On spruce needles. Emmet County, Aug. 31, fide Atk.

Inocybe fastigiata Schaeff. (in sense of Bresadola). Ground, hemlock and cedar woods. Emmet County, fide Atk .

Inocybe geophylla, var violacea Pat. Ground, hemlock woods. Emmet Co., Aug. 27, fide Atk.

Inocybe Godeyi Gillet. (At least closely related.) Ground, cedar swamp. Emmet County, Aug. 27, fide Atk.

Inocybe rhodiola Bres. (Syn.=I. Jurana. Pat.) D. M. C. Wayne County, Sept. 5, fide C. H. K.

Inocybe scabella Fr. (In sense of Bresadola.) Ground, cedar swamp. Emmet County, July 31, fide Atk.

Inocybe scabroides Atk. (in. ed.) Ground, hemlock woods. Emmet County, August 3, fide Atk.

Inocybe suboohracea var. Burtii. Pk. Ground, cedar swamp. Emmet County, Aug. 31, fide Atk.

Inocybe trechispora Berk. Ground, hemlock swamp. Emmet County, Aug. 7, fide Atk.

Lactarius camphoratus (Bull.) Fr. Ground and debris, hemlock woods. Emmet County, July 26, fide C. H. K.

Lactarius chrysorrheus Fr. D. M. C. Grosse Isle. Sept., fide Pk.

Lactarius deceptivus Pk. D. M. C. Oak woods. Wayne County, Sept., fide C. H. K.

Lactarius lignyotus Fr. On rotten wood, hemlock woods. Emmet County, July 20, fide Pk.

Lactarius piperatus (Scop.) Fr. Ground, maple woods. Emmet County, Sept. 5, fide C. H. K.

Lactarius pyrogalus (Bull.) Fr. Ground, hemlock and birch woods. July 26, fide C. H. K.

Lactarius regalis Pk. D. M. C. Ground, oak woods. Wayne County, July-Sept., fide Pk.

Lactarius scrobiculatus (Scop.) Fr. Ground, hemlock swamp. Emmet County, Aug. 5, fide C. H. K.

Lactarius theiogalus (Bull.) Fr. Ground. Port Huron. Aug. 20, fide C. H. K.

Lactarius uvidus Pk. Under bushes, border of a lake. Emmet County, Sept. 12, fide C. H. K.

Lactarius vellerius Pk. Ground, maple and poplar woods. Emmet County, Aug. 10, fide C. H. K.

Lentinus vulpinus Fr. Rotten wood. Wayne and Washtenaw Counties, Aug., fide C. H. K.

Lentinus chrysopeplos B. & C. On old logs. Emmet County, July 13, fide C. H. K.

Leptonia placida Fr. D. M. C. Grosse Isle, fide Atk.

Leptonia solsticialis Fr. On rotten log. Emmet County, Sept. 1, fide Atk.

Lepiota asperula Atk. Hemlock woods. Emmet County, Aug., fide C. H. K.

Lepiota Boudieri Bres. var. albifolia. On very rotten wood, beech woods. Emmet County, Aug. 25, fide Atk.

Lepiota clypeolaria Bull. On debris, hemlock woods. Emmet County, Sept., fide C. H. K. and Pk.

Lepiota cristatatellus Pk. Among debris, hemlock woods. Emmet County, Sept., fide C. H. K.

Lepiota eriophora Pk. D. M. C. Grosse Isle. Sept., fide Pk.

Lepiota felina Pers. Emmet County. Among debris, hemlock woods. Emmet County, Aug. 23, fide C. H. K. and Pk.

Lepiota gracilis Pk. Very rotten log, beech and hemlock woods. Emmet County, Sept., fide Pk.

Lepiota granosa Morg. Logs, maple and beech woods. Emmet County, Sept. 16, fide C. H. K.

Lepiota gloioderma Fr. Ground, hemlock woods. Emmet County, Aug., fide C. H. K.

Marasmius papillatus Pk. On roten hemlock logs. Emmet County, Aug. 20, fide C. H. K.

Marasmius longipes Pk. On leaves, sticks, etc. Washt. County, Sept., fide C. H. K.

Mycena pelianthina Fr. Ground, maple woods. Emmet County, July 13, fide C. H. K.

Mycena crystallina Pk. Sphagnum swamp, on moss. Emmet County, Sept. 1, fide C. H. K.

Mycena immaculata Pk. Ground, cedar swamp. Emmet County, Aug. 28, fide C. H. K.

Mycena metata Fr. Among moss, cedar and hemlock swamp. Emmet County, Sept., fide C. H. K.

Mycena purpureofusca Pk. Mossy hemlock logs. Emmet County, Sept. 4, fide C. H. K.

Naucoria cuspitada Pk. (in ed.) Among debris, hemlock woods. Emmet County, Sept. 4, fide Pk.

Naucoria platysperma Pk. On dung hills. Washt. and Emmet counties, June, fide Pk.

Nolanea conica. Pk. Rotting logs, hemlock and beech woods. Emmet County, July 15, fide C. H. K.

Nyctalis asterophera Fr. On old Russula nigricans. Form without gills. Maple woods. Emmet County, Aug. 11, fide C. H. K.

Omphalia lilacifolia Pk. On rotten hemlock log. Emmet County, July-Aug., fide C. H. K.

Omphalia rugosodisca Pk. On rotting hemlock logs. Emmet County, July 31, fide C. H. K.

Paneolus subbalteatus B. & Br. D. M. C. In mushroom bed. Detroit, Sept., fide Pk.

Panus augustatus Berk. (syn.=Pleurotus stratosus Atk.) Emmet County, July 13, fide C. H. K.

Paxillus panuoides Fr. On rotten wood, maple woods. Emmet County, July 31, fide C. H. K.

Paxillus involutus (Batsch) Fr. Very rotten wood, hemlock woods. Emmet County, July 3, fide C. H. K.

Paxillus atrotomentosus, Batsch.) Fr. Stumps, hemlock, woods. Emmet County, Aug. 30, fide C. H. K.

Pholiota acericola Pk. On maple logs. Emmet County, July 14, fide C. H. K.

Pholiota caperata Pers. Ground, hemlock woods. Emmet County, Aug. 27, fide C. H. K.

Pholiota rugosa Pk. On debris, hemlock woods. Emmet County, Sept. 12, fide C. H. K.

Pleurotus circinatus Fr. D. M. C. Grossle Isle. Sept., fide Atk.

Pleurotus petiolaris (Bull.) Fr. D. M. C. Wayne County, fide Pk.

Pleurotus porrigens Pers. On rotten wood, maple woods. Emmet County, Aug. 21, fide C. H. K.

Pleurotus septicus Fr. On logs, hemlock woods. Emmet County, Sept. 5, fide C. H. K.

Pleurotus subpalmatus Fr. D. M. C. Grosse Isle. Sept., fide Atk.

Pleurotus sulfuroides Pk. On log, hemlock woods. Emmet County, fide C. H. K.

Pluteolus carpophilus Pk. Washt Co. On manure around trees. Campus, Ann Arbor. June, fide C. H. K.

Pluteolus aleureaotus gracilis. Pk. On wood, cedar swamp. Emmet County, July 18, fide C. H. K.

Pluteus seticeps Atk. On rotting hemlock logs. Emmet County, July 19, fide C. H. K.

Pluteus umbrosellus Atk. (in. ed.) D. M. C. On wood. Wayne County, Sept. 19, fide C. H. K.

Psathyra microspora Pk. On turf, roadside along Huron River. Washt. County, Oct. 11, fide Pk.

Psilocybe arenulinus Pk. D. M. C. In sandy garden. Detroit, Oct. 16, fide C. H. K.

Russula abietina Pk. Hemlock woods, on very rotten logs. Emmet County, Aug., fide C. H. K.

Russula atropurpurea Pk. Oak woods, hemlock woods. Oakland and Emmet Counties, fide C. H. K.

Russula crustosa Pk. Ground. Washt. County, Sept., fide C. H. K.

Russula decolorans Fr. Ground, in woods. Emmet County, Aug., fide C. H. K.

Russula declorans Fr. var. constans Karst. Washt. County, fide Pk.

Russula granulata Pk. On lawn, Ann Arbor. July, fide Pk.

Russula fragilis (Pers.) Fr. Hemlock woods. Very rotten logs. fide C. H. K.

Russula furcata (Pers.) Fr. D. M. C. Woods. Aug, fide C. H. K.

Russula nigricans Bull. Ground, maple woods. Emmet County, Aug. 1, fide C. H. K.

Russula olivacea (Schaeff.) Fr. Hemlock woods. Emmet County, fide C. H. K.

Russula roseipes (Sec.) Bres. Hemlock woods. Emmet County, Aug., fide C. H. K.

Stropharia Johnsoniana Pk. D. M. C. Grosse Isle, Sept. 11, fide Pk.

Tricholoma acre Pk. D. M. C. Oak woods. Wayne County, Sept. 19, fide C. H. K.

Tricholoma columbetta Pk. (one of the varieties). Ground, oak-woods, Oct., fide C. H. K.

Tricholoma Russula Schaeff. D. M. C. Ground, in woods. Wayne County, Oct., fide C. H. K.

Tricholoma rutilans Schaeff. On logs, hemlock woods. Emmet County, July 13, fide C. H. K.

Tricholoma resplendens. Fr. Ground, hemlock woods. Emmet County, Sept. 8, fide C. H. K.

Volvaria pubescentipes Pk. On debris, in hemlock woods. Emmet County, July 17, fide C. H. K.

University of Michigan.

A STUDY OF RUDBECKIA HIRTA L.

W. J. BEAL.

In the summer of 1903, 1904 and 1905, I was fortunate in finding large numbers of plants of this species growing on rather hard land among bushes of cut-over land.

These hirsute plants are usually considered weeds, as they often grow in meadows and flower in June about the time of timothy. They vary much in height, even when growing near each other, 25-100 cm. high. The disk is half-oval, dark purple, hence its name, Black-eyed Susan; the orange rays usually drooping.

The rays range in number from 8-34; in length from 1.5-7 cm.; in width, from 3-11 mm.

During these three summers I selected some thirty-five plants, each of which showed some peculiarity that interested me. Among these were dwarf or low plants; some with few, others with many rays; some with short rays, others with long rays; some with narrow rays, others with wide ones; one in which the rays extended horizontally; some with rays brown or dark red near the base; some in which the thirty-four rays were all tubular or "quilled" for 12-30 mm. of their length. Rays were found that were broad at the apex, or pointed, the apex split and curled under. There were twisted rays and flat ones. In rare cases six or more very narrow rays came out just above the wide ones and curving upward over the disk.

Among the most remarkable of the selections was a single plant found last summer (1905), where there were many thousands to select from. This plant could not appropriately be called "black-eyed Susan" but "green-eyed Susan" would be better, as the head was yellowish-green instead of dark purple as were all others seen. I have no specimen here of the "green-eyed Susan," but I saved seeds for planting.

Among my seedlings was a dwarf not over three inches high. All seedlings not desirable I pull up and destroy. For lack of room I have gradually discarded a portion of the selections that had been made. Late in the fall of 1905 the best of the selections were scattered, one in a place in different portions of the two acres comprising the garden. In many cases seedlings have been grown, in each case near the parent plant which produced the seeds.

The plants of all species vary, but some are more plastic than others. I venture the statement that any botanist who shall patiently study all stages of several hundreds of plants of one species will be surprised at their differences. Some sedges, red clover, and Indian corn, are especially variable. Every farmer knows how difficult it is to maintain constant, or nearly so, any race of plants when propagated by seeds.

The thirty-five plants selected were carefully moved to a spot in the

botanic garden which is shaded from the sun by brush overhead. Some seedlings were grown under this screen. The question is now forced upon me, "What shall I do with these plants to insure what would be called good results, so far as beauty of color and form are concerned?"

"Perhap the florist already has enough plants that bear yellow or orange flowers, such as sunflowers, zinnias, marigolds, and silphium."

The plants transplanted last year, with cultivation improved much in size, and size of flowers. To assist in securing variations, I shall give the plants a change of soil, moisture, exposure to sun, and shade. They will each have plenty of room, and good cultivation. A few of these may be crossed, but my chief reliance will consist in growing each apart from others and selecting to a type during several generations, attempting to fix one peculiarity at a time.

(Twenty-nine heads of flowers in variety were on exhibition as herbarium specimens.)

Agricultural College.

A STIMULUS TO THE PRODUCTION OF CELLULOSE AND STARCH.

J. B. DANDENO.

To organize starch or cellulose, in the laboratory, by chemical processes merely, has never, so far, been accomplished. Plants develop cellulose in the ordinary processes of growth, and they produce starch in the chloroplast under proper conditions of light and temperature, if the necessary substance be present; but the action of the protoplast seems to be necessary for the development of either starch or cellulose. Such action is very likely a chemical one, but the chemist has never been able to imitate the process, much less to duplicate it. Anything, therefore, which tends to throw light upon the question is eagerly sought by both the chemist and the physiologist, to say nothing of the bacteriologist.

The whole problem of the development, the interactions and the functions of cellulose in plants is probably one of the most interesting in the whole field of physiology, but it is only one phase of the problem that will be examined here. *Shaeropsis malorum Pk.* (black rot of apple) seems to produce cellulose in the cell-walls of the apple in the course of decomposition of the fruit. It also produces starch in the cells invaded by the mycelium of the fungus.

Fungi build up cellulose, closely resembling the cellulose of higher plants, in the walls of their cells. Such cellulose, however, de Bary called Fungus-cellulose because, in some cases, a modification of the ordinary cellulose test reagents had to be employed in order to bring out the typical cellulose reaction. The process of transformation of cell wall substance and cell content of the host plant, into the body of the parasite, is a process common enough in the vital activities of all plant parasites, and it is indeed a necessary operation in the life of the parasite. But that the fungus parasite can stimulate the host plant to build up starch, or thicken its cell walls, is a different matter. This occurs not infrequently among certain groups of parasites, e. g., Puccinia graminis. This fungus stimulates the host plant to produce more cells in the neighborhood of the mycelium than in a like portion of the barberry leaf which is not affected. It stimulates, therefore, the production of cells, and, at the same time, in these cells, starch grains are formed. These starch grains are what might be called stored starch. Though they are in the portion of the host in which starch is organized. But in each case the host is a living plant, and, as such, it is capable of modifying its tissue as the result of response to stimuli. With the black rot of apple, the case is somewhat different, because the apple itself (the fruit) has long been severed from the tree and is no longer considered a growing, or, even, a living organ. It has also been

considered that fungi which work on stored apples are *pro tanto* saprophytic, because the apple (the seeds excepted) was regarded as a non-living body.

The black rot in a week or ten days after inoculation produces in the apple enormously thickened cell walls, and this thickening goes on until the whole fruit becomes mummified and dry. To the unaided eye the apple then has on its surface an ebony-like appearance. Sections show thickened walls and starch grains in the cells. (It should be said that starch, though *occasionally* found in stored, ripe apples, is not generally present.) In the specimen here examined, care was taken to select such apples as possessed no starch, for inoculation purposes. Most of the cell contents of the apple had apparently disappeared. The liquid content seemed to be the portion which had gone to build up cellulose and to produce starch. But this conclusion is mainly inference, drawn from the appearance of the cells afterwards, and from the fact that the apple shrivelled without apparently losing much water. Inoculated fruits were kept under different conditions in moist atmosphere so as to see whether the shrivelling was wholly due to a mere drying out or to a change from liquid to solid within the tissue. A further corroborative test was made by injecting a strong fungicide within the apple to see if, when the fungus was killed, and certainly the contents of the apple cells also, the shrivelling action went on, to see if the process was a mere drying out process. This experiment supported the other tests, showing that it was not a mechanically drying out process.

That many fungi produce an enzyme capable of dissolving cellulose is a matter of common knowledge. It is due to this dissolving ferment that fungus hyphae are able to bore through the mass of cellulose which constitutes the wall of the cell of the host plant. This cellulose wall is, as a rule, not quite uniform in its physical (perhaps chemical also) constitution. The portion first formed by the cell is usually more readily liquified or dissolved than is the remainder. When a potato or apple is boiled, the part first formed (middle lamellae) is dissolved away and the cells become separated from one another. When tissue is macerated a similar condition results. An apple decomposed by a fungus has its cells separated similarly. The middle lamellae are dissolved away by the hyphae penetrating the tissue. It is quite largely due to the fact that the middle lamella is more soluble in the presence of the enzyme accompanying the fungus mycelium, that fungus mycelia grow most frequently between the cells rather than into them, although the latter method would seem at first sight to be infinitely easier.

This middle lamella has usually a different optical density from that of the other portions of the cell wall, hence it can generally be recognized, especially in lignified tissue, by examination with the microscope.

The mummified apple, affected with the black rot, is practically in a state of preservation for an indefinite period, unless placed for a considerable time—a few days—in a moist place. If moisture be applied, the mycelium commences to grow, and a portion of such mummified apple may then be used to inoculate other fruit. From this it might be inferred that the enormous development of cel-

lulose in the cell walls of the apple, is an adaption favorable to the fungus in tiding it over from time to time, or from season to season. This inference is further supported by the fact that in such mummy apples no perithecia are produced. Perithecia are common enough in affected crab apples, but in these there is very little development of cellulose in the cell walls as compared with common apples so affected. This is partly true also with respect to the formation of starch, for there is much less to be found in apples in which the perithecia are developed, than in those in which they are not.

Upon examination of affected fruit from time to time after inoculation with black rot, it may be seen that, as the cell walls become thickened, the quantity of starch grains become lessened. This cell-wall thickening takes place from without, proceeding towards the center, until practically the whole liquid content of the cells of the fruit is changed into solid. A section perpendicular to the surface of an apple, well on towards mummification, shows the cells at the outside to possess walls ten to twenty times as thick as in the unaffected apple, and the cell-content a small mass shrivelled up and with almost no liquid. These cells contain occasionally a starch grain or two. The cells which are about thirty cells deep from the surface of the apple, possess walls two or three times as thick as in the unaffected apple, and quite large quantities of starch grains, in some cases as many as forty or fifty grains in a cell, with some other solid content and some liquid. The cells between those two extremes, shade off with regard particularly to cell wall thickening, number of starch grains in a cell, other solid cell-content, and to liquid cell-content.

The mycelium of the black rot is intercellular, as a rule, but occasionally it enters the cells, not, however, by producing regular haustoria, but by means of the ordinary mycelium which sometimes not only enters the cells but also passes right through them. In the enormously thickened walls, the mycelium may readily be seen, especially if the section be stained, branching all through the cellulose. The character of this mycelium is thin-walled with hyphae of very small diameter. Occasionally a strand of the mycelium is rather large, but these large strands occur mainly *between* the cells and where wall thickening has not proceeded to so large an extent. This large mycelium is sometimes found near the surface, but in such cases it grows right through the cells, penetrating the walls on both sides. This has more numerous septa than the finer hyphae which ramify so profusely through the cellulose.

The black coloring of the affected apple is due mainly to the character of the cell contents of the outer layer of the cells. The content of these cells is very dense in color. The mycelium of the fungus in the region of this layer of cells is slightly dark in color, while that penetrating the tissue of the apple farther in, is colorless. (The mycelium is colorless on culture media.)

In the crab apple, where perthecia are formed, the mycelium is often almost black in color, especially that portion in the body of, and around, the perithecia. But the mycelium does not destroy the fruit as stated by Tubeuf and Smith* but actually seems to act as a sort

* Tubeuf and Smith p. 472,—"The mycelium permeates and distroyes the skin of the fruit, which, in consequence becomes dried up and mummified".

of preservative against decay, more especially in such fruits as those upon which perithecia do not grow.

That a mycelium should stimulate the formation of starch within cells of such tissue as an apple which has long since been detached from the tree, is surprising because the cells are no longer living in the sense that cell division could be further carried on; and indeed the nuclei seem to be, in many cases, entirely disorganized. But it has long been regarded that the nucleus is the functional organ of the cell, without which none of the usual operations of the cell can be carried on. The thickening of the cell walls and the formation of starch grains seem to be produced independently of the nucleus of the apple cell, and it would therefore appear as though the stimuli produced by the presence of the hyphae of the fungus effect the same results in this respect as that which might have been produced by a nucleus. But the nuclei which might happen to remain alive and intact in the fleshy part of a ripe apple, do not seem to be capable of developing thick walls, or of performing the function of building up starch grains after the fruit comes to maturity. The carbohydrates are present in the cells, and these carbohydrates are so modified by the stimulus of the fungus, that part becomes starch and part cellulose. There is, however, a suggestion that starch grains are formed first, and then, later, dissolved and built up into cellulose. It was not possible to see this process being carried on, and the suggestion arises only out of the fact that when the walls are thickest the number of starch grains is smallest.

The conclusion is naturally reached, therefore, that a fungus may actually stimulate the direct operation of *building up*—as the process of cellulose formation has frequently been called,—as well as the almost universal one of *breaking down*. That it can do this in a body outside itself, and the body not in a growing condition, is a fact at once curious to a high degree. The formation, then, of cellulose and of starch, in the laboratory, may not be quite so stupendous a process after all.

Among parasitic fungi it commonly happens that starch grains are present in the neighborhood of the fungus mycelium, but this has been ascribed to the fact that the host plant—as a living, growing plant—responds in this way to the stimulus produced by the parasite. Galls are developed on plants as a result of all the stimuli induced by the sting of an insect. But an insect could not produce a gall in a leaf severed from the plant. So that when the fungus causes a development of cellulose or of starch grains in the cells of an apple in winter time, or any time after the apple is detached from the tree, it is performing an operation which seems to be different from that of the parasite growing upon the living plant. From this arises the question as to when a plant, or part of a plant, is really dead; and this is probably one of the most interesting as well as the most subtle questions in the field of physiology today. It is thought that the peculiar phenomena resulting from the operation of the black rot fungus upon the apple throws some faint rays of light upon the question. The flesh of the apple can scarcely be considered dead, even though the nuclei may have become disorganized, because the other cell content is capable of response to stimuli, and can act apparently of its own motive force.

It should also be said that several fungi are capable of causing the

development of starch grains in the cells of the fleshy part of the apple. This is true notably of apple scab, and also to some slight extent of soft rot (Penicilium), and of bitter rot. But these two last mentioned dissolve the cellulose, acting through the middle lamellae, and separating the cells, thus causing that soft condition which is commonly termed "rotten." The black rot, however, though it commences by dissolving the middle lamellae, does not go on dissolving the cellulose but seems to content itself with boring through the mass of cellulose which it has succeeded in causing the apple cell to build up.

The following conclusions may be logically made from this discussion and from the experiments involved in it:

(1) Cellulose and starch are developed directly in the cells of a ripe apple (long since detached from the tree) by the fungus *Sphaeropsis malorum Pk.*, and in rather large quantities.

(2) The development of cellulose seems to be an adaptation of advantage to the fungus in enabling it to tide itself over unfavorable periods of time; in such cases no perithecia are produced.

(3) The apple is, to a certain extent, in a state of preservation when this fungus has operated upon it for some time. The ebony-like apple is not easily subject to attacks of other fungi.

(4) At first it might appear as though the fungus *caused* the production of cellulose, but it is rather the result of a stimulus upon the cell content induced by the fungus.

Agricultural College.

A FUNGUS DISEASE OF GREENHOUSE LETTUCE.

J. B. DANDENO.

In a large part of western Michigan, a very destructive disease, commonly affecting greenhouse lettuce, renders the production of head-lettuce, at times, a not too profitable industry. In some years, thousands of dollars' worth of lettuce has been so injured as to be practically of no market value. This disease has been already reported from Michigan and some other states under the name of Marsonia* perforans, E&E., but it is not a Marsonia at all for reasons which shall be mentioned presently.

In 1896, in the report of the Ohio Agricultural Experiment station, appears a description of the fungus by A. D. Selby, and also Ellis & Everhardt's technical description which reads: "Spots small, irregular in shape, 1-2 mm. in diam., pale soon deciduous, acervuli 100-120 micron in diam, or by confluence larger. Conidia abundant, clavate, or wedge shaped, hyaline, faintly uniseptate, (11-15)x(2½-3) microns, exceptionally reaching 20 microns long." * * * "Marsonia perforans, E&E., n. sp." Mr. Selby states: "Specimens were sent to Dr. J. B. Ellis, who proposes the name *Marsonia perforans,* E&E., n. sp., for the fungus." Mr. Selby himself proposes the common names Lettuce Leaf Perforation.

The accompanying photograph† shows the appearance of affected leaves and the general habit of the fungus. Even from this, it is quite apparent that it is the same fungus as that reported by Mr. Selby, though the detailed descriptions differ materially from that given by Ellis and Everhardt.

Description:—Parasitic on leaves of cultivated lettuce,—particularly head-lettuce cultivated in greenhouses—; produces brownish spots which on the blade become holes, and on the mid-rib elongated sunken areas.

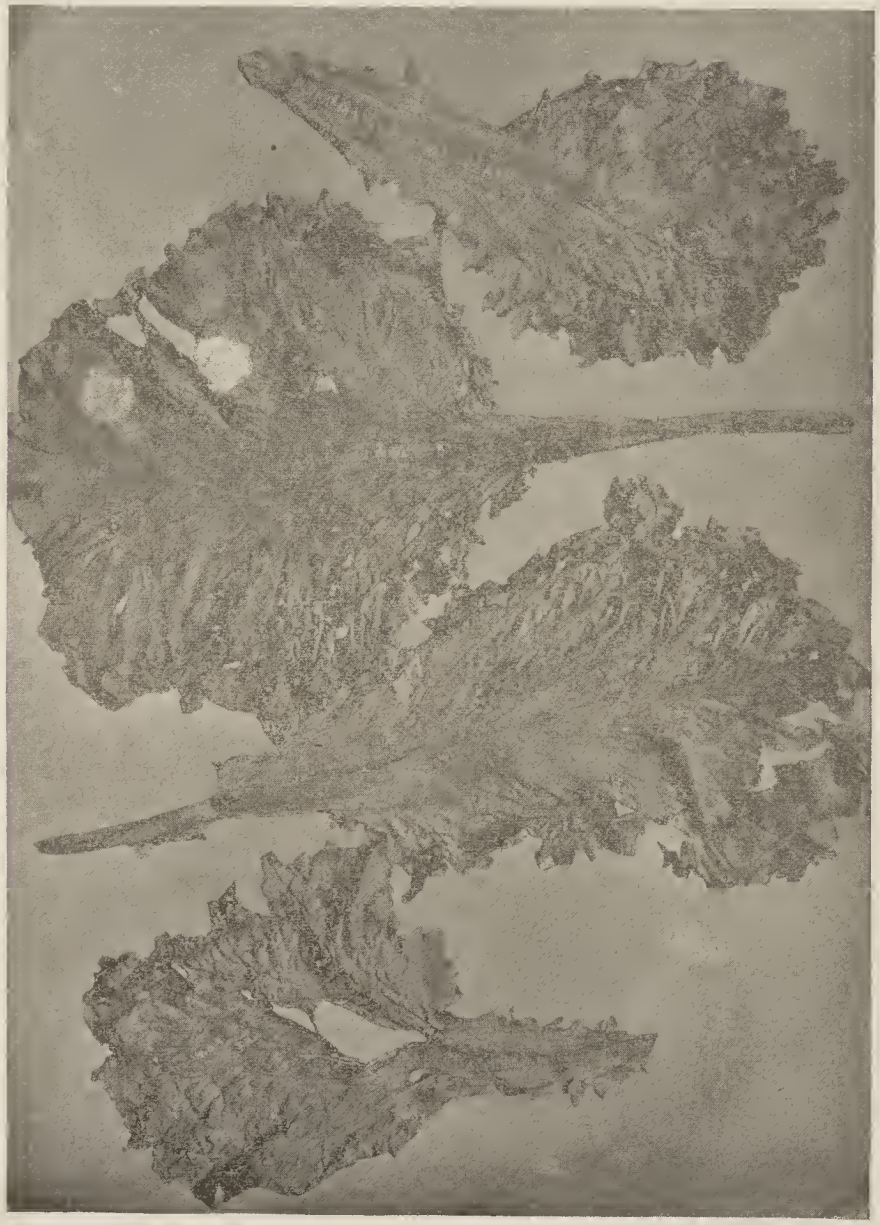
Mycelium,—septate with numerous septa, sparingly branched, found almost wholly on the surface, haustoria entering the cells, but occasionally the mycelium penetrates through the opening of the stomata; found typically running in parallel strands. (Fig. 4.)

Conidiophores,—short, unbranched, somewhat bottle-shaped (Fig. 2), about 15 or 20 microns long, frequently once septate and erect or nearly so, bearing one condium.

Conidia,—once septate, narrowly obovate, 15x4 microns, generally not quite symmetrical, having a tendency towards crescent-shaped, easily detached from the conidiophore, hyaline, frequently growing in clusters of two to five. (Fig. 2.)

* Sometimes spelled Marssonia.

† I am indebted to Professor E. E. Bogue for the photograph.



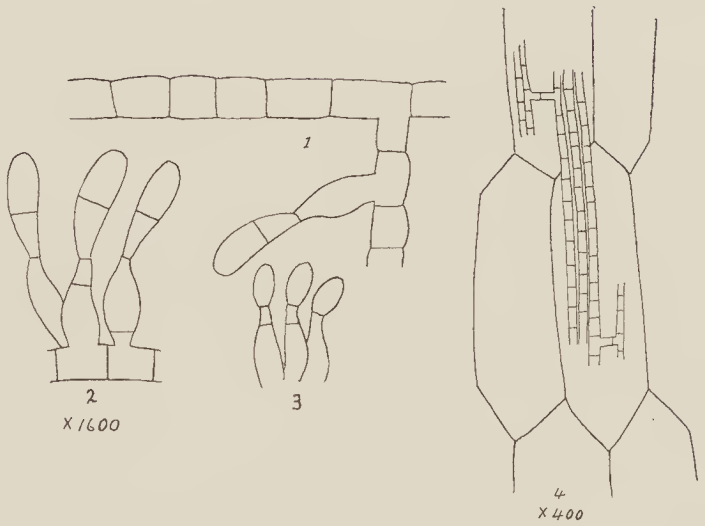


Figure 1—Filament of mycelium showing conidiophore and a conidium magnified about 1,600.

Figure 2—Conidiophores and conidia. They quite frequently occur in clusters of three or four.

Figure 3—Young conidia.

Figure 4—Mycelium found on the surface of a midrib of a leaf; occasionally branching, but generally running parallel filaments lengthwise with the petiole; almost wholly on the surface.

Photograph shows the general appearance of affected lettuce leaves.

The name here proposed for the fungus is *Didymaria perforans*. It corresponds very closely to Engler and Prantl's description of Didymaria.

The main reasons why this fungus can not be a Marsonia are:

1. The mycelium is superficial while the mycelium of Marsonia is sub-epidermal.

2. There are no stromata, while, Marsonia, has typically well defined stromata.

Other details indicate also that it is not a Marsonia; but the above two in themselves are sufficient to throw it out of that genus. In fact it would also throw it out of the group—the Melanconiales—which are separated from the Hyphomycetes chiefly by the presence or absence of a stroma. The Melanconiales have a well defined stroma while the Hyphomycetes have none.

It is quite true that both these genera are but provisionally made in view of the fact that they belong to that group of supposed imperfect forms known as the *Fungi Imperfecti;* but so far as they are known, these provisional genera are of as much importance for the sake of convenience as any other genera.

Agricultural College.

THE AERATING SYSTEMS IN PLANT TISSUES.

J. B. DANDENO.

For all living plants oxygen is an essential substance. For green plants both oxygen and carbon dioxide are essential. So that the relation of plants to these two gases, is an important one. Though the final word has not yet been said concerning all the details of the relatownships, yet considerable advance has been made towards a knowledge of the underlying principles within the last ten years.

Oxygen is necessary for the activity of the protoplasm in the living cell. When plants are dormant, very little oxygen is required; when they are growing rapidly, a very considerable amount is necessary. The amount of oxygen necessary for some of the lower forms of plants is surprisingly large. For instance—man inhales about .4 per cent of his body weight in twenty-four hours of oxygen; certain molds consume 2.2 per cent of their body weight of oxygen; active bacteria 72 per cent of their body weight. And as a general rule, the volume of oxygen consumed is equal to the volume of carbon dioxide set free. The process is known as respiration.

In living cells, in the presence of chlorophyll, sunlight and water, carbon dioxide may be built up into carbohydrates. If respiration be going on in a green cell at the same time, the carbon dioxide liberated is, under normal conditions, utilized in the formation of carbohydrates. This utilization of carbon dioxide in the process of formation of starch or other carbohydrate, is termed photosynthesis. Both these processes may be carried on at the same time in the same living cell, if all conditions be favorable.

For regulating the interchange of these two gases, several special plant structures have been developed. The more important of such structures are:—stomata, lenticels, aerenchyma, unmodified epidermel cells, empty dead cells, and intercellular spaces. Stomata may occur on leaves or branches but never on roots. Lenticels are found on branches and sometimes on roots. Aerenchyma is a peculiar tissue developed on the surface of the roots of certain plants which grow in mud. Epidermel cells, if not cutinized or suberized, are permeable to gases in whatever part they may occur. Intercellular spaces are common in almost every tissue of the plant. Empty dead cells, such as occur in pith and wood, always contain more or less air.

The openings of the stomata are extremely small—about 1,000 of them being required to cover an opening whose area is one square mm. These, of course, are too small to allow dust particles, or water in a liquid state, to pass, unless under high pressure. Gases pass only very slowly. The force which causes the passage of gases, either inward or outward, is the vital activity within the living cells coupled with ordinary atmospheric pressure. The white velvety appearance of

the under sides of leaves and of the surfaces of young stems and roots, is due quite largely to the presence of air in the intercellular spaces. If the intercellular spaces of a leaf be injected with water, the leaf loses its whitish appearance, and soon dies owing to the lack of oxygen. These air spaces in a leaf have intercommunication with one another, and a direct communication with the openings of the stomata; so that the aerating system of a leaf is a continuous one. The openings of the stomata are very numerous, sometimes as many as 250 per square mm. The aerating system is best developed in leaves, probably because of the great vital activities carried on there. Aquatic plants have their stomata and intercellular spaces of leaves on the upper sides of the leaves, and it is due to the air in these intercellular spaces that the leaves float. The materials in the tissues are actually heavier than water, and consequently would sink were it not for the buoyancy brought about by the presence of air among the cells. Stomata occur on green stems and in structure and operation are similar to those on leaves.

Lenticels, which are eruptions through the outer cortex of branches, originate from stomata, but become much larger, and many cells are involved as growth of stem enlarges them. They serve the function of interchange of gases, but in one respect they are better adapted to this than are the stomata. The outer cells are corky and therefore slightly permeable to air, but not to water, consequently the mycelium of a fungus can not enter as it could through the openings of the stomata. As the lenticel enlarges, new cells are formed by the cork cambium beneath, and those new cells become corky later, partly through the action of the air. If the amount of corky tissue be very great it becomes almost impermeable to gases, but as growth proceeds, the lenticel breaks open the corky layer and this renews the communication. The cork cambium forms new corky cells beneath.

On the roots of some bog plants, an outside tissue similar to that of the lenticel, excepting that it covers a much greater area, serves a function similar to that of the lenticel. It permits the passage of gases but not water. This tissue is called aerenchyma.

As roots have no stomata and few lenticels, air must pass in through the epidermal structures directly. This is particularly the case with all young growing roots, some of which are capable of gaining sufficient oxygen directly through the epedermal cells from water. But the great majority of land plants are not able to do this. The roots of such plants must obtain oxygen from the air in the soil; and young vigorous roots require a very considerable amount.

Air in wood cells and vessels, in pith and the like, may or may not be in a position to furnish a supply of oxygen to the living cells. However, it seems to serve the function of buoyancy and strength, and indirectly connects the aerating systems of roots, stems and leaves.

There can be no question then as to the importance of a knowledge of the aerating systems of plants. The whole subject of drainage is one directly involved. The presence of water sufficient to cover the roots of plants for any length of time, is death to such roots, owing to the supply of oxygen being cut off. The question of soil tillage is one quite largely of rendering the soil thoroughly permeable to air. It is all the more important to have soil in such condition because the total amount

of air in the neighborhood of the roots is necessarily limited, owing to the fact that the space is largely occupied by soil. And if decomposing organic matter be present, a considerable amount of carbon dioxide will be liberated, and this gas, if abundant, may be quite injurious to roots. Moreover, decomposing matter in the soil always draws upon the supply of oxygen there, so that less is available for the roots. Soil is liable to become baked, and, in the case of grass fields, to be so coated over as to reduce very materially the supply of available air to the roots. Old pastures ought to be harrowed up. Orchards should not remain sodded. Top crusts should be broken. And the fact should not be lost sight of that young roots are parts which grow rapidly and consequently need plenty of oxygen. There is no question that plants differ widely in regard to their power of adapting themselves to unfavorable aeration of soil, but the principle holds rigidly throughout. And what is true of roots is true also of other underground parts—stems and leaves.

Concerning the part of the plant above ground, the matter seems of less consequence only because the air supply is self-regulative, owing to the fact that it is abundant at all times, and it is usually accessible without any help from man. The parts above ground have, therefore, a great advantage over the underground structures with respect to the aerating system. Moreover, the air is constantly in motion and the plant never suffers from lack of change of air. The motion itself is of advantage in bringing about a current of air which continually bathes the external aerating organs.

It is obvious, however, that if any interference be made with the special aerating system, or the aerating organs. it will result in injury to the plants. Some people smear over whole twigs, branches, and even trunks of trees with a greasy wash, not knowing that they are choking up the air passages and injuring the trees.

Although lenticels are usually not visible on old stems of trees, yet eruptions, much larger than lenticels, are being continually formed as the tree increases in size. The cork cambium is ever present to heal the wound as soon as a break occurs, and such eruptions or cracks are often quite large. New eruptions serve as lenticels. On smooth-barked trees, such as poplar, they may be readily seen, a single one often as large as a silver dollar. These form part of the aerating system of the tree trunk, and the air which enters at these places is near the growing tissue in the cortex, just where it is needed. And it has been proved that carbon dioxide is given out at these places. The heart-wood cells are wholly filled with air, and the sap wood contains more or less, consequently there is air both within and without the growing tissues. The air in the wood cells is, however, not freely available for use in growth. It serves mainly the purpose of buoyancy and strength for the stem.

The leaves being the most active organs of the plant, have consequently, the best aerating system, both as to means by which air may pass in or out, and as to aeration within the tissue. The stomata are not the only means. In many cases the epidermal cell walls permit an interchange of gases. If the stomata be clogged up with grease, the plant suffers. If the whole surface be smeared over, the leaf dies. If a

leaf be immersed in water, it is equivalent to depriving it of oxygen. Aaerial leaves will not live under such conditions. The farmer knows that if his winter wheat be covered over with water or ice, for any length of time, the crop is destroyed. The destruction is mainly due to the fact that the supply of oxygen is cut off. If a pool of water lie on a grain field so as to submerge the crop for some time, the plants are killed. In the winter time vital activity in the wheat is very slow, consequently the plants would not die as quickly as they would if submerged in summer. Winter wheat may remain alive uuder snow because there is enough air iu the snow to supply all the needs. Snow does not shut off the air supply, and if the plants be wholly dormant they may survive for months without air, but winter wheat is not wholly dormant, even when growth seems to be stopped.

The aerating system of stems of corn, sugar-cane, bamboo and the like, is a special one. These have no lenticels. As the stem of corn (for example) increases in diameter, new fibro-vascular-strands are formed, and new tissue is developed near the surface, causing the epidermal cells to separate, here and there, and sub-epidermal cells are forced out to the surface. Through these young cells, aeration takes place. These epidermal cells which are forced out soon become lignified and thick walled like the others, especially on the outer side; and were it not for the fact that new cells were coutinually pushed to the surface, aeration could not take place in the stem. In a cross section of a stem of corn, it can be seen that here and there on the surface are a few cells—two or three—which are thin-walled as compared with the regular epidermal cells. It is through these thin-walled cells that aeration takes place. This method of growth is not only a provision for enlargement of circumference of the stem, therefore, but also a provision for aeratiug the growing tissue. The surface of the stem never becomes rough as it does with dicots, for the outside layer is composed of cells which are touching one another. They are not loose as they are in the body of the lenticel of dicots. The air must pass in through the walls and not between the cells, and as a geueral rule where oxygen may pass in, carbon dioxide may pass out.

Water plants and marsh plants have an internal air system of their own. This consists of a system of intercellular spaces running lengthwise with the stems or leaves, and occupying the greater part of the plant body. The submerged parts are not provided with stomata, but interchange of gases is maintained by the internal atmosphere within the large spaces just mentioned. This internal atmosphere is replenished by the diffusion which takes place in connection with the surrounding atmosphere. In marsh plants, such as rushes and sedges, which stand partly in the water, the large vertical intercellular spaces form connecting channels through which the atmospheric oxygen, without being exhausted, can reach the organs growing deep in the mud surrounded by marsh gas, and otherwise cut off from any communication with the air.

In corn and many other monocots, there is a comparatively large intercellular space within the mature fibro-vascular-bundle. This intercellular space runs the whole length of the bundle and is quite analagous to the air spaces in aquatics and semi-aquatics. In fact these intercel-

lular spaces indicate an aquatic habit in the ancestors—not very remote —of the corn.

Hollow stems, in many of the more rapidly growing herbaceous plants, constitute a direct means of aëration of the stem and the more remote internal growing structures.

Submerged plants gain their oxygen and CO_2 directly from the water, and once gained they may be stored up in the intercellular spaces for future use. This supply serves a double purpose, namely, to furnish the needs of the plant, and to keep it erect in the water. To keep up sufficient buoyancy in sea water requires much less gas content and intercellular space than in fresh water on account of the higher specific gravity of sea water. The fact may be easily understood by comparing the structure of the tissues of marine plants with those growing in fresh water.

Anerobic respiration ought not to be omitted in any discussion of aeration, because it seems to present a contradiction with respect to the almost universal need of oxygen in respiration. Anerobes seem to gain all the energy they require from chemical action—other than oxidation—within the tissues. One of the resulting products produced by some anerobes, is sulphuretted hydrogen, and in this case it appears that the chemical action resulting in this compound furnishes energy to the plant similar to that furnished by the operation which results in the formation of CO_2. But it will depend upon the specific character of the organism itself whether it has the power of utilizing the energy latent in a given substance. Some maintain that the operation is *always* an oxidation process,—no matter what may be the product given out,—that it may be only an *end* product of which there may be a series of two or more, one of which being oxidation, but not carbon oxidation.

In connection with this, a word should be said about intra-molecular respiration. In the case of many seeds, germination can be carried on in the absence of atmospheric oxygen, or pure oxygen; and because CO_2 is liberated by the process, the conclusion is made that oxygen must be obtained from the molecules of other substances within the cells. So that if young seedlings be deprived of air, they are able to carry on the function of respiration to a limited extent. In such respiration, alcohol as well as CO_2 is one of the resulting products.

Respiration, photosynthesis and *transpiration* are all involved in the process of aeration. Transpiration is usually limited to mean the passage of water—in suspension in the air—from the tissues out to the free atmosphere. Roots, stems and leaves are involved in respiration; green leaves and green stems in photosynthesis; leaves and stems generally in transpiration.

Movement and interchange of gases are augmented mainly by the following:—change of temperature; diffusion caused by interchange of gases; assimilation; transpiration; pressure and the moisture of the air; movement of the plant produced by wind or water.

In some books dealing with botanical matters, the term "breathing" is used with respect to interchange of gases, but the term is misleading because by inference it involves a comparison with breathing of animals. They are not comparable because breathing in animals implies

chiefly muscular contraction and other processes which enlarge or reduce the aerating cavity. In plants there is no such action.

An actual problem illustrates, probably, more vividly than any discussion, the enormous amount of air used by plants in the process of transpiration alone: At a temperature of 82° F., an oak requires 1,111,111 cub. ft. of air per day to carry off the water of transpiration; a sunflower requires 1,500 cub. ft. per day; and one acre of cabbage requires 25,024,000 cub. ft. per day. These figures are calculated from the actual amount of water transpired and from the amount of water vapor held in suspension in the air at a given temperature. At a temperature of 72° it would, of course, require more, and at 92° less, providing we assume that the plant transpires as freely at these temperatures, which is obviously an assumption which does not hold in nature, but, at the same time, serves the purpose of illustration. At the temperature 72°, 82°, 92°, with the assumption just stated, the amount of air would be in the proportions, 32, 23, 16.

Agricultural College.

PLANT DISTRIBUTION AT MUD LAKE.*

L. H. PENNINGTON.

Mud Lake is one of Michigan's numerous post glacial lakes. It is located about eleven miles northeast of Ann Arbor, and was at one time an arm of Independence Lake. Now, however, it is almost entirely filled with marl and peat deposits, the only open water being a strip about (60) sixty rods long and (20) twenty rods wide at its widest part. A glance at the map (Fig. 1) shows that the peat-forming plants have first come into the irregular arms of the old lake and made its margin very regular as compared to the original shore. Of the several arms Mud Lake presents the most interesting and instructive field of study, because it shows all stages in bog formation from open water to the spruce-tamarack forest and the marsh-meadow. Plant succession may be studied here under natural conditions as well as under changed conditions due to clearing and to burns. Many of the tamaracks have been taken away for fuel or fence posts, loads of spruces have been cut annually for Christmas trees, and severe fires, fifty years ago and again eighteen years ago, burned over large areas.

It is customary to group plants into various societies. For convenience we may divide the plants within and around the bog into two large groups of societies; first, the mineral soil societies, and second, the peat bog societies. Although some plants are common to both groups, and in some places the societies of one group merge into the societies of the other group so gradually that it is hard to draw a line between them, yet, as a rule, the plants are very different for the two groups and live under very different conditions.

The plants of the first group may be considered with respect to the three habitats in which they are found. These habitats are, first, the well-drained hills, covered with an oak-hickory society; second, the low ground or the level, poorly drained soil, covered with a white ash-beech-maple society or by an elm-black ash-swamp oak society; third, the old lake shore, covered by a great variety of species, due partly to the fact that within the space of a few feet there may be xerophytic, mesophytic, and hydrophytic conditions, and partly to the fact that this strip in many places has been changed but little by cultivation. Thus many introduced plants, commonly called weeds, as well as many native plants, grasses, sedges, composites, etc., become established here.

The peat bog societies were studied in detail. Writers have classified peat bog plants in various ways. Five principal zones will be taken up here; first, the zone of marginal plants; second, the zone of tamaracks

* Contribution 90 from the Botanical Laboratory of the University of Michigan.
This work was done in the summer of 1905 under the direction and with the assistance of Dr. George P. Burns.

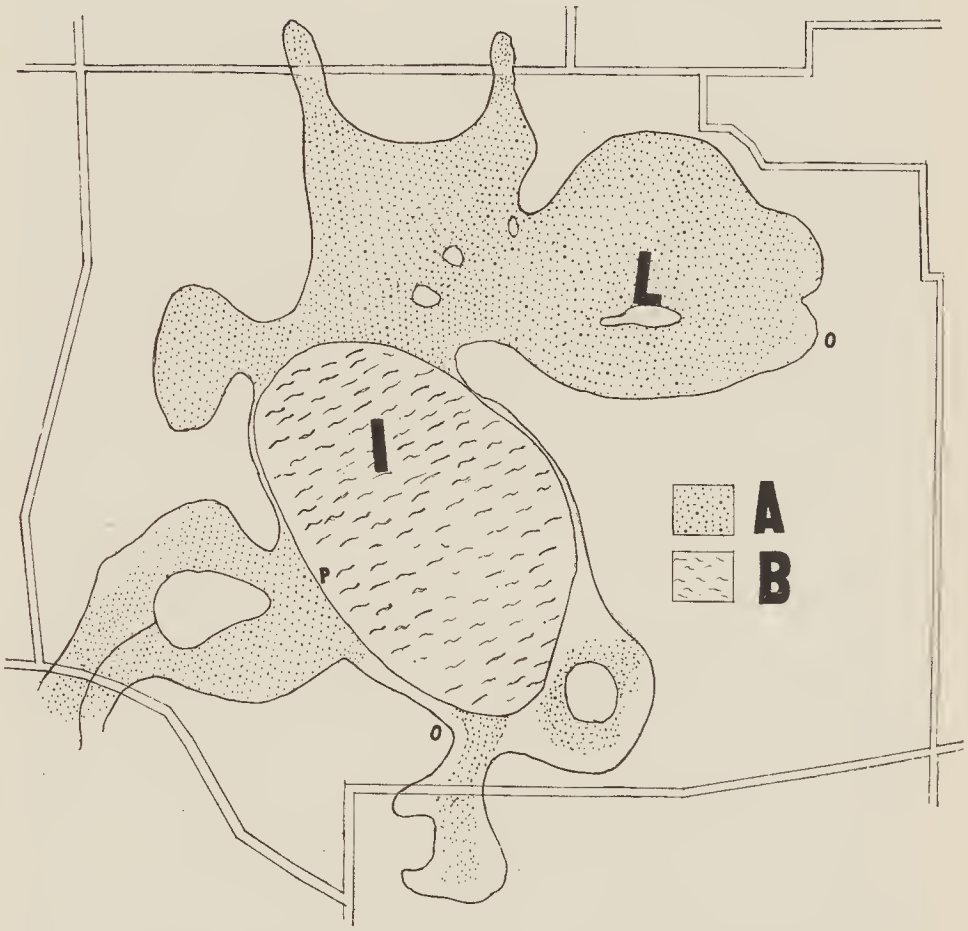


FIG. 1.—Independence and Mud Lakes, showing present distribution of plants.
I—Independence Lake.
L—Mud Lake.
A—Peat deposit.
B—Open water.
O—Old Lake shore.
P—Present lake shere.

and black spruces; third, the zone of Cassandra and Sphagnum; fourth, the zone of floating plants, and fifth, the zone of water plants. Under the head of marginal zone is included all that part of the bog which lies next to the shore and which now shows no signs of ever having borne tamaracks. Its plant societies are intermediate between those growing upon the mineral soil on one side and the typical bog societies on the other. The majority of its plants, however, are from the mineral soil societies. The width varies from fifty to four or five hundred feet. The principal societies in the marginal zone are, (a) the marsh-grass meadow society, (b) the cat-tail society, (c) the willow society, and (d)

the poplar-elm-osier society. This great variation in the marginal zone societies is due to several causes, chief among which are the following: the variation in the ground water level in the margin; the frequent denuding of the margins by fire; the ease with which plants get into these denuded areas from the surrounding country by means of wind and water; and the presence of mineral matter which is washed down from the high ground, together with that which the larger plants may get by sending their roots down through the peat.

The tamarack zone includes all those parts which are now or have lately been covered with tamarack or tamarack and spruce forests. At the present time there are, (a) the typical tamarack society, (b) the tamarack-spruce society, (c) the Aronia-Vaccinium society, and (d) the tamarack areas which have recently been denuded by fire.

The typical tamarack society is a three-layered forest in which the tamaracks form the upper layer, the shrubs, such as Vaccinium corymbosum, Aronia nigra, Ilicioides mucronata, and Rhus vernix from the second, and plants such as Aralia nudicaulis, Pteridium aquilinum, Woodwardia Virginica, Rubus hispidus, Unifolium Canadense, Coptis trifolia, and Cornus Canadensis the third.

In the spruce-tamarack society there are about an equal number of each species. The spruces, however, shut out so much light that very few plants grow under them.

Where man has cut away the tamaracks, the shrubs, Vaccinium corymbosum and Aronia nigra, make so rank a growth that nearly everything else is shaded out, and we find now what may be called a Vaccinium-Aronia society. If, however, the shrubs are cut away with the tamaracks, or if a spruce-tamarack society is cleared away, other plants get a foothold, principally those whose seeds are carried long distances by the wind, as Carduus, Epilobium, and Chamaenerion, or by birds, as Rubus and Prunus. Occasionally tamarack seedlings are found in these completely cleared areas.

Where fire has denuded a tamarack area, it has usually, not only destroyed all the plants, but burned away the peat to a depth of from two inches to three or more feet. In these denuded areas Populus tremuloides soon gets a foothold, then from one side, bog plants come in, and tamarack seedlings often get started, so that, in the course of many years, the tamarack society is restored. In the burned regions next to the margin, the bog plants are not able to compete with the plants from the upland, which quickly advance into the marginal zone after each fire.

The Cassandra-Sphagnum zone consists chiefly of two areas, entirely surrounded by the tamarack zone. The plants in this zone are chiefly Chamaedaphne calyculata, growing in and half covered by a thick mat of Sphagnum. This zone has never borne tamaracks nor spruces, but small clumps of Vaccinium, Gaylussacia, Larix, and Picea, which appear here and there, show that, in the natural course of succession, this Sphagnum-Cassandra zone will be covered by a tamarack or a spruce-tamarack forest.

The zone of floating plants entirely surrounds the open water. It is composed chiefly of sedges and the marsh fern, Dryopteris Thelypteris. A part of this mat is composed almost entirely of cat-tails.

The zone of water plants consists chiefly of Scirpus lacustris, Pontederia cordata, and large quantities of Nymphaea advena, which grow in the water and loose peat just in front of the sedge mat.

FACTORS DETERMINING DISTRIBUTION.

A considerable amount of discussion has been carried on about the historical factor[1] in the distribution of bog plants. In such work as the writer attempted, however, particular attention was paid to local factors, and the historical factor can be ignored.

A straight line, beginning at the northeast side and running south by southwest, was laid out across the bog in such a way as to cross all the zones mentioned above. (Fig. 2 AB.) To correlate the depth to the present distribution, borings were made every hundred feet to determine the depth and, in a general way, the nature of the deposits. All parts of the bog and the lake which have a depth of more than eight feet are underlaid with marl, which forms beds often sixteen to twenty-five feet in thickness. To determine accurately the relative position, size, and frequency of the plants and the relation of the societies to each other, a plot was made for a strip forty to fifty feet wide along this line.

Beginning at the north end the line first crosses a marshy meadow, which is one hundred fifty feet wide at this point. The peat is very dark and has a maximum depth of eight feet. The owner said that previous to the last fire he had mowed this meadow annually for marsh hay, but that since that time he had been unable to mow it at all because the surface is too uneven. He affirmed that the peat was burned to a depth of six feet in some places. The higher parts of this meadow, where it was burned the least, are now covered with marsh grasses and a few sedges; lower places are filled with wet-soil sedges, blue flags, sensitive ferns, and cowslips; and still lower places, which are seldom free from open water, contain water-plantains and cat-tails.

In the next two hundred feet the depth increases from eight to thirty-five feet. The peat becomes lighter as the depth increases. At the place of greatest depth, it is a yellowish brown and rests upon ten to twelve feet of marl. Evidently this area was once covered with tamaracks, which have been nearly all burned off. At the present time the first one hundred feet on the land side is covered with willows, and the rest of it on the bog side with Populus tremuloides. Very many other plants are found growing with the willows and with Populus tremuloides. Of thirty species listed for the willow society at this point, only eight species are characteristic of bog flora; of twenty-eight species listed with the Poplars, fifteen are characteristic of the bog. Almost exactly as the depth increases from ten to thirty-five feet, the Populus tremuloides decrease in size and numbers, and are replaced by a Sphagnum-Cassandra society. This society extends four hundred fifty feet across a basin twenty to thirty feet deep. Beyond this is another burned area very similar to the first Poplar area except that Poplars have not grown so large, young tamaracks are more common, and the number of mineral soil species is much less. Abruptly following this burned

[1] Transeau, Bot. Gaz. 40, p. 351.

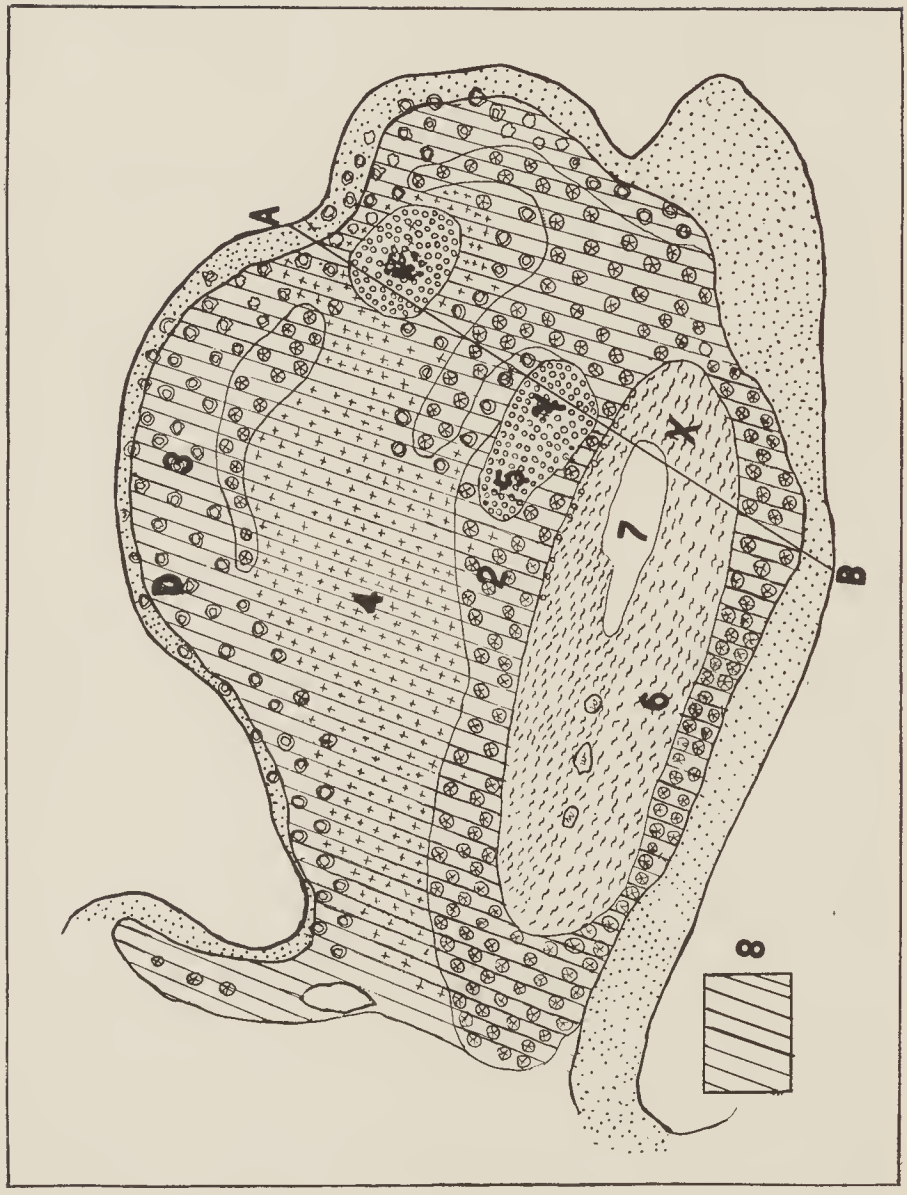


FIG. 2.—Mud Lake Bog.
A-B—Line of profile map.
1—Marginal zone, indicated by the dotted area within which are the following zones:
2—Tamaracks, or tamaracks and spruces.
3—Broad leaved trees on burned area.
4—Blueberries, etc., mostly cleared.
5—Cassandra and Sphagnum.
6—Floating mat.
7—Open water.
8—Zone lately covered with tamaracks.

area is a zone, two hundred feet wide, of old tamaracks and spruces, growing upon firm brown peat nine feet deep. Almost the only plant here besides the Larix laricina and Picea Mariana is Vaccinium corymbosum, which grows among the trees wherever the shade is not too dense. Beyond the tamarack-spruce society is another burned area, which is practically the same as the last one mentioned. The surface of these burned areas is even now, after eighteen years of filling by Sphagnum, often twelve to eighteen inches lower than the surface of the peat in the tamarack-sprnce zone. The deepest of these burned depressions are often full of water for long periods so that sedges and cat-tails are found growing in them.

Next to the last burned strip is another Sphagnum-Cassandra society, five hundred feet across, growing over a basin twenty-five to sixty feet deep. Over the deepest parts the peat is very loose. Into this society besides the tamaracks and the blue-berries, the spruces are also making their way, following the tamaracks. An observation that the spruces are nearly always in circular clumps led to the discovery that in many instances a circle of spruces surrounds a dead or dying tamarack whose light has been nearly all shut off by the growing spruces. In some places younger stages may be seen where a fringe of young spruces is coming up under the lower branches of a tamarack, which has already made considerable growth and has shaded out the Sphagnum and Cassandra beneath its branches. Light is the controlling factor. The tamaracks shade out Sphagnum and Cassandra and give the spruces an opportunity to get started; the spruces, if they are numerous enough, shade out the tamaracks and nearly everything else within the shadow of their branches. Other plants within this society are Sarracenia purpurea, Scheuchzeria palustris, Andromeda polifolia, Oxycoccus Oxycoccus, Eriophorum Virginicum, Blephariglottis ciliaris, Cypripedium acaule, Monotropa uniflora, etc.

Between the last mentioned Sphagnum-Cassandra society and the zone of floating plants which surrounds the lake, there is a tamarack society, which is less than one hundred feet wide where the line crosses it. At this point the peat under the tamaracks is eight feet deep and the marl about fifteen feet. This tamarack society is a part of the continuous tamarack forest which entirely surrounds the floating mat except for short space at the southeast.

The bog enclosed within this zone of tamaracks is nearly elliptical in outline, about one hundred sixty (160) rods long east and west and forty-five (45) rods wide at its widest part. The lake which lies somewhat east of the centre of the bog, is fifty-eight (58) rods long and eighteen (18) rods wide. The bog here is from twenty-four (24) feet to forty (40) feet deep, the lower sixteen to twenty-five feet being marl and the upper eight to fifteen feet very loose peat. The mat at the northwest side and at the east end of the lake is composed almost entirely of cat-tails; the rest of it is composed largely of sedges and marsh ferns. From the south and the west sides tamaracks are advancing upon the bog, while Sphagnum is not very abundant. On the north side young tamaracks are rarely found, but Sphagnum and Cassandra are advancing rapidly and smothering out the other bog plants, so that a narrow strip on that part of the bog is a true Sphagnum-Cassandra society.

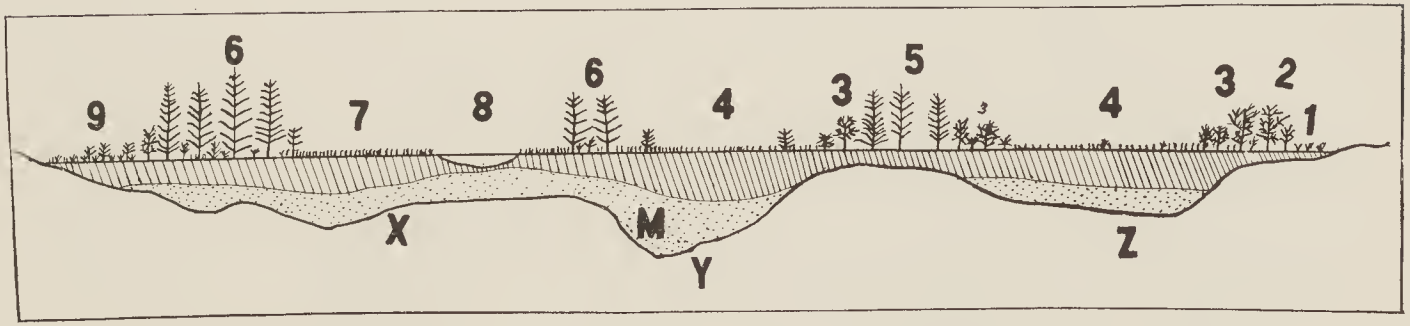


FIG. 3.—Profile along the line AB in figure 2.
M—Marl; above this is a layer of peat.
1—Grasses and sedges.
2—Willows.
3—Poplars.
4—Cassandra and Sphagnum.
5—Tamaracks and spruces.
6—Tamaracks.
7—Floating mat.
8—Open water.
9—Grasses, sedges, and shrubs.

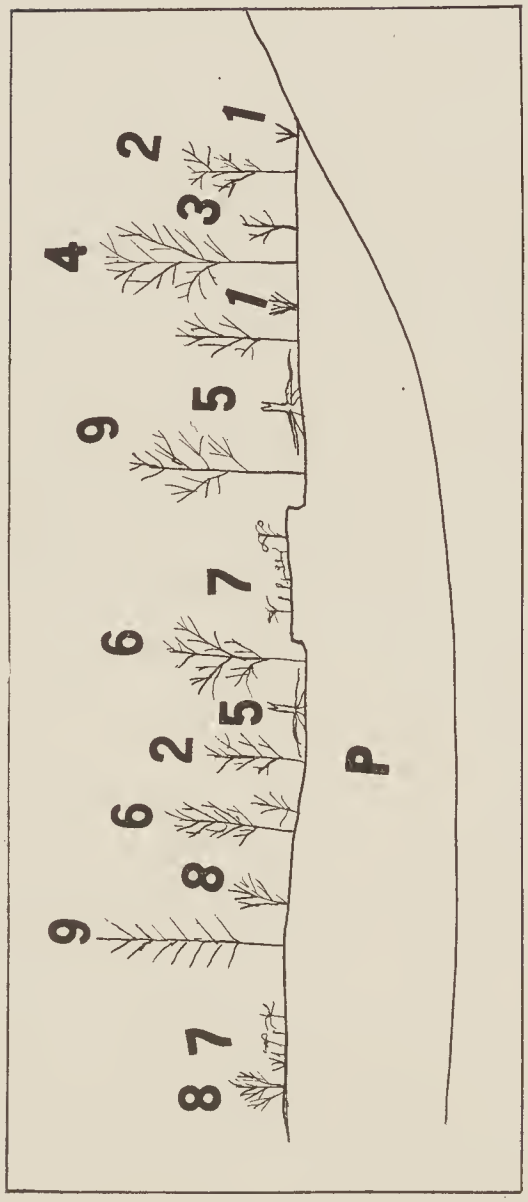


FIG. 4.—Diagram of burned margin.
1—Sedge.
2—Willow.
3—Osier.
4—Elm.
5—Tamarack stump.
6—Populus.
7—Typical bog plants.
8—Blueberry.
9—Tamarack.

The mat seems to be advancing rapidly over the lake by growing from the margin and by the increase in the size and number of detached pieces of the mat, which have floated out and become lodged upon the rootstocks of Nymphaea advena. Other plants found in this floating zone are Zizania aquatica, Eriophorum polystachyon, Sagittaria latifolia, Comarum palustre, Menyanthes trifoliata, Decodon verticillatus, Salix myrtilloides, Marchantia polymorpha, Drosera rotundifolia, etc.

The tamarack forest on the south side is from one hundred feet to three hundred feet wide, and rests upon from eleven to twenty-eight feet of brown peat and marl. Between this tamarack forest and the shore is the marginal zone, which shows little evidence of having ever been burned over and which has no distinct marginal depression. Besides grasses and sedges, growing in this zone there are several low shrubs, Rosa Carolina, Spiraea salicifolia, Dasiphora fruticosa, etc.

The profile through the several zones (Fig. 3) shows that the younger zones of floating plants and of Sphagnum and Cassandra lie over deeper basins which must be the last places to be filled with peat and to be covered with bog plants. The water plants fill the water nearly to the top with very loose peat, the mat grows out upon this, then tamaracks come upon the mat, either directly, as upon the south and west sides, or after an intervening Sphagnum-Cassandra stage, as upon the north side of the large basin (Fig. 2 and 3, X) and in the smaller basins (Y and Z). Although tamaracks may come directly upon the sedge mat, young spruces are first found in the Sphagnum-Cassandra zone. These results correspond with the results which have been obtained by Burns* and Pettee.† From Fig. 3, it might seem that the basin *X* should have been filled before the deeper basin *Y*, but Fig. 2 shows that *X* is very much larger than *Y*. Moreover, borings show that parts of *X* are deeper than the part through which the profile was taken. It is reasonable to suppose that a zone of water plants could fill the small basin *Y* in much less time than an equally wide zone could fill the large basin *X*.

In a consideration of the burned areas, it is evident that the peat is seldom burned evenly or to a uniform depth. There may be irregular depressions, where every living thing was totally destroyed, lying adjacent to strips which were merely burned over and in which the majority of the plants were not killed. A good illustration of this is found in the north part of the swamp (Fig. 2, D), (Fig. 4). Along the margin is a common marginal society of Salix, Populus, Ulmus, Cornus, Solanum, Caltha, etc. In wet seasons the ground is covered with more or less water. There are no evidences of burns near the shore, but several rods from it, half burned tamarack stumps with all their upper roots exposed and partly burned show that fires must have lowered the leved at least eighteen to twenty-four inches. The plants, however, are in no way different here from those found near the shore. About fifteen rods from the shore there is a strip from one to several rods in width, which does not seem to have been burned out. It is higher than the rest of the ground so that its surface is comparatively dry at all seasons of the year, and upon it are such plants as Aralia

* Report Michigan Academy of Science, 1904, P. 76.
† Report Michigan Academy of Science, 1905, P. 126.

nudicaulis, Pteridium aquilinum, Rubus hispidus, and Unifolium Canadense, none of which are found in the lower burned places, and all of which are common in the tamarack society. Beyond this higher strip there is more of the burned area with practically the same plants that are found near the shore, in addition to a few bog plants, Vaccinium, Aronia, Betula, etc.

Fire has been commonly used for the last century in clearing this country. In dry seasons fire, spreading from the uplands, naturally comes first into the margins, which are known to be the driest parts of a bog in a dry season. Every year many bogs are burned over, and the effects of a single fire may remain for many years. Since there are places on the margin having little or no depression, since the marginal depression is most marked where fires are known to have occurred, and since plant societies in depressions known to have been caused by fire are the same as the plant societies usually found in marginal zones, it is reasonable to think that marginal depressions and marginal plant societies are due largely to the destruction of the peat and the bog plants by fire.

CONCLUSIONS.

1. Peat bogs are heterogeneous habitats and require detailed study.
2. Depth of water is a primary factor in the distribution of the plant societies in a bog.
3. Plant succession in older parts of this bog is brought about largely by fires.
4. The replacing of tamarack forests by blueberry swamps is due to clearing.

University of Michigan.

SOME BOTANICAL ERRORS FOUND IN AGRICULTURAL AND CHEMICAL TEXT-BOOKS.

W. J. BEAL.

Every once in a while I find that I have been making some errors in teaching Botany. I am not alone in these respects, for I find many errors in books that treat of botanical topics. I can now recall many errors taught me in zoology and botany by the distinguished men, Louis Agassiz and Asa Gray of Harvard. How much more difficult it must be for a teacher or writer of books to be always right when he undertakes to cover two or three departments of science, such as botany and chemistry, or botany and agriculture. Botany, as we now know it, is a science that is comparatively young, and during the last twenty years has grown with astonishing rapidity. To show the folly of one man's undertaking to cover a broad field in science, I will give one illustration.

In 1873 was published in New York a translation of a book, entitled "The Universe," by F. A. Pouchet, M. D., with an introduction by Arnold Guyot, Ph. D., of Princeton, N. J. I make a single quotation:

"In the marshy forests of Southern America, Providence has intrusted this task to another distilling plant, the Purple Sarracenia, the structure of which is no less eccentric. Its leaves, uniting at their edges, are transformed into elegant amphorae, the narrow opening of which is surmounted by an ample green auricle decorated with scarlet red veins, to which the species owes its names. These cups, present from the empire of Flora, and which rise from spot to spot at the feet of the traveller, are filled with pure and delicious water, for the benefit of which he is all the more grateful that he is encircled by nothing but marshes, the water of which is lukewarm and nauseous."

This is our common pitcher plant of the bogs. The fact is, the water in these pitchers abounds in rotten insects and worms, which no one would ever think of drinking. The author attempted to cover too much ground, and of course failed in the attempt.

Under the heading as given on our program, I shall give a few illustrations as found in the writings of four authors,—not by any means all the errors that could be found.

"Agriculture," by Dr. William P. Brooks, of Massachuetts Agricultural College, is a recent publication. For an illustration of the flower of wheat, he speaks, on page 397, of "the feathery pistil," where he should say feathery stigma, and on page 421, "the seeds of orchard grass and those of rye grass look much alike, and as the rye seed can be much more cheaply grown than that of orchard grass, it is sometimes mixed with the latter." He probably had in mind the fact that the seeds of meadow fescue resemble, not those of orchard grass, but those of rye grass. On page 502, he speaks of great variations in the yield of pota-

toes tested in plots where the seed-tubers had been purchased, probably overlooking the difference in yield of the hills from which the seed-tubers had been grown—a very common error.

"The Cereals in America," a recent book by Prof. Thomas F. Hunt, of Cornell, is usually accurate, at least so far as the botany is concerned. He made free use of "The True Grasses," by E. Hackell, who is an expert on grasses. Prof. Hunt says: "When a grain of wheat germinates, it throws out a whorl of three seminal or temporary roots." He shows a microphotograph of a cross section of a grain of wheat through the embryo, showing tips of three rootlets before germination. Had this section been made obliquely across the lower end of a kernel of wheat, he would have found five roots instead of three, not in a whorl, but standing nearly in one plane. The center root is largest, appearing first in germination; next appears one on each side; and later another on each side, making five.

Speaking of the inflorescence of oats, he says: "A typical panicle is nine to twelve inches long, containing from three to five whorls of branches." Instead of whorls he should have said "half-whorls."

"How Crops Feed," by Prof. Samuel W. Johnson, of Yale University, deals mostly with chemistry and physics. In the paragraphs headed "Decay of Vegetation," the author says: "When a plant or any part of a plant dies and remains exposed to air and mosture at the common temperatures, it undergoes a series of chemical and physical changes, which are largely due to an oxidation of portions of its carbon and hydrogen, and the formation of new organic compounds." Eremacausis is the old word used to express these changes—a slow chemical combustion in the decay of wood. In the process of decay, the important part played by bacteria and saprophytic fungi is not even mentioned.

Watt's Dictionary of Chemistry has made a change in the meaning of this word and defines Eremacausis or Decay as "A slow combustion taking place in presence of air and water, and accompanied by a kind of fermentation."

"How Crops Grow," by Prof. Samuel W. Johnson of Yale University, has had a great run. About two-fifths of the pages are devoted to the life of the plant and may safely be placed under the term botany, besides much of the other three-fifths contains a good deal of plant physiology. The date on the title page reads 1902.

On page 41, read "Every agricultural plant is an aggregate of microscopic cells, i. e., is made up of minute sacks or closed tubes, adhering to each other. Although the highest magnifying power that can be brought to bear upon the mebranes of the vegetable cell fails to reveal any apertures in them,—they being, so far as the best assisted vision is concerned, completely continuous and imperforate—they are nevertheless readily permeable to liquids."

Contrast the above with a statement of Sachs in 1880: "Every plant, however highly organized, is fundamentally a protoplasmic body forming a connected whole," and Sachs was right. In other words, all the protoplasm in a plant is connected by innumerable pits or holes in all the cell walls.

On page 49, "In potato starch the grains are egg or kidney-shaped and are distinctly marked with curved lines or ridges, which surround

a point or eye." As every agricultural sophomore now knows, a typical grain is ovate, much flattened and very smooth.

Again, the cell walls in the interior of a grain of wheat are extremely thin and delicate, but the illustration in "How Crops Grow," make them thick as in the wood of basswood.

On page 247, "When a potato is boiled the starch grains swell and the cells, in consequence, separate from each other, a practical result of which is to make the potato mealy." How is it with most boiled or baked potatoes which do not enlarge or break open and yet the starch grains enlarge?

On page 247, "The pulp of an orange is the most evident example of cell tissue. The individual cells of the ripe orange may be easily separated from each other," and are a quarter of an inch long. A moderate magnifier reveals the fact that the walls of these so-called cells of an orange are composed of two or more layers of small cells making the wall of a sack.

On page 273 we read "Small tubers (tubercles) are frequently found on the roots of the garden bean." If the book were revised to 1902, the text should contain something concerning the nature and value of these tubercles.

On page 292 is a large illustration purporting to represent a section of a vascular bundle of a stem of corn. It is a caricature, opposite which Dr. Dandeno wrote: "Very bad; not correct in any particular." This is too complicated for me to attempt to explain satisfactorily to those present.

Figure 58, on page 309, claims to represent the under surface of a leaf of potato. The stomata are each represented by one oval cell open in the center. There should be two cells for each stoma, as every sophomore knows. The author adds that "the round bodies in the guard cells of the pores are starch grains, often present in these cells, when not existing in any other part of the leaf." The fact is, the bodies he calls starch grains are chloroplasts or chlorophyll granules.

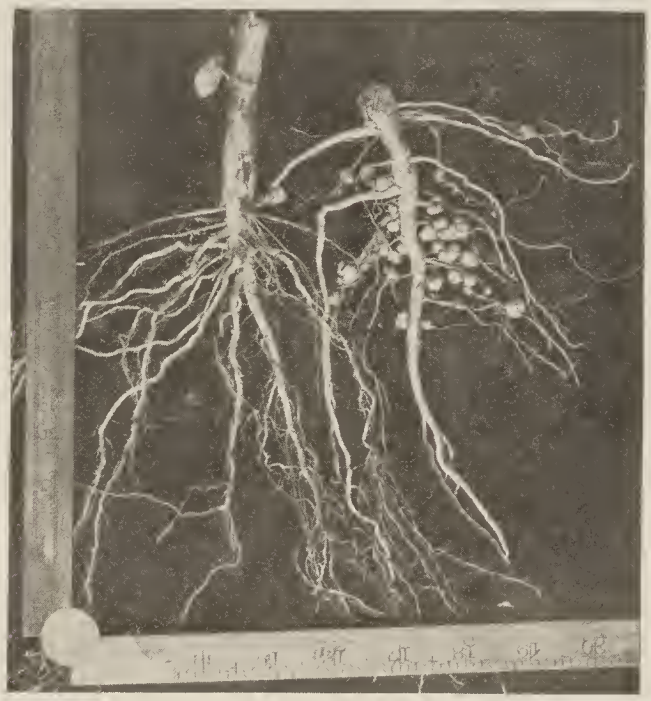
On page 351 is a sentence reading as follows: "The radicle (of seedlings) divides and subdivides in beginning the issue of true roots." The radicle of a seedling was so named long ago with the supposition that it was a root, but later the name caulicle was applied, because it was found to be the first stem of a plant. Roots spring from the free lower end of a caulicle, but the radicle does not divide and subdivide in the formation of true roots.

Agricultural College.

SOME NOTES ON NODULES.

C. D. SMITH.

Not infrequently contributors to our magazines and metropolitan journals undertake to frighten humanity with the ghost of old Malthus. They hold up to public view the proposition that humanity is likely to starve to death in the not remote future because of a growing scarcity of fixed nitrogen in the soil. We hear of waterfalls being devoted to the manufacture of electricity to be used in the conversion of the free



Ogemaw Soy Beans After Cow Peas.

nitrogen of the air into nitrate. How many such factories it would take to supply the nitrates utilized by a crop of an acre and necessarily lost through various channels in the growing of the crop, newspaper writers have not yet told us. It might not be out of place to refer them to Mrs. Partington and her mop and her vain attempts to keep back the Atlantic Ocean, as a fair prototype.

It has fallen to the Farm Department of the Experiment Station to carry forward some investigations in the fields as to the work performed in gross by the bacteria in the nodules on the roots of certain legumes. The whole subject is so familiar to the audience to which this paper is addressed that I shall not attempt here any systematic statement of the etiology of these nodules or their methods of operation. I shall simply report certain definite experiments as a contribution to the literature on the subject. Naturally the technical, and therefore the more valuable part of the work concerning this interesting phase of

Soy Beans after Soy Beans.

plant life has fallen to the Department of Bacteriology, leaving me the field work on plots of such legumes as have been grown at the college.

The first observation of record in the technical part of this nodule business was the difference in the number and size of the nodules on soy beans growing on muck upon which various fertilizers had been applied. In field 13 of the college farm, east side of the lane and adjacent upon the northward to the Grand Trunk railroad, there is an area of muck used for several years in a series of experiments to test the influence of various fertilizers on the productivity of the soil. The long way of the plots was east and west, the width north and south, being generally two rods. Each plot was treated with single fertilizers or some combination of fertilizers. Across the whole series of plots, soy beans were sown in rows eighteen inches apart and rather thickly in the row.

Mr. Potts, the station foreman, noted a great variation in the number and size of the nodules on the several plots, although the seed had not been inoculated, and although the ground had never borne soy beans before. Below are given the kinds of fertilizer used and the number of inoculated plants, or at least the number of plants bearing nodules out of a hundred plants examined, on each plot. Sometimes the nodules were single, large and close to the main stem of the plant. Sometimes there were a multitude of small nodules scattered along the roots and rootlets like pearls on a string.

Soy Beans after Cow Peas.

Plot 1. Leached ashes, 24% of plants infested with nodules, usually one nodule per plant and that on the main stem and large. In one case only, were there small nodules resident on the smaller side roots, six cases of small nodules on main stem.

Plot 2. Sand an inch deep over surface of muck and harrowed in; 37% of plants bore nodules, sixteen with nodules on side roots and twenty-one with nodules on main root. These nodules were invariably large and attached closely for the entire length of the nodule to the main stem. The surfaces of these nodules were also reticulated, a net work of white ribs over a dark background. Occasionally, on this plot there would be a string of large nodules on some side root, similar to the large ones on the main root. These nodules would be reniform or spherical and varying from a quarter of an inch to three-eights in

diameter. In ten cases only were there small nodules, less than a sixteenth inch in diameter.

Plot 3. No fertilizer, 28% bearing nodules; 11% with large nodules near main stem, all others with smaller nodules, in eight cases at least miliary, very small and either scattered all over the root system or, more frequently, gathered into masses about a common center. On one plant there were twenty-six small nodules differing widely from each other in form and appearance; on another thirty-nine small ones scattered in several small masses. The point is that the grouping and general appearance of the nodules and of the plants themselves was widely different on these two plots where the sole apparent variant was the application of the ashes.

Plot 4. Air-slaked lime. The original soil is fairly rich in nitrogen, about .5 per cent. It is fair to assume that the lime aided in setting free nitrogen, possibly as ammonia; 16% with nodules. Usually a single nodule per plat and that close to the main stem, one case of six large nodules another of five small ones, in both cases close to the stem.

Plot 5. Commercial fertilizers, 34% bearing nodules. The roots were widely spread out through soil and with superabundant root hairs. Best root systems so far in the series, notwithstanding better infestation with nodules. Nodules mainly medium to small in size, in six cases only near main stem, otherwise on side roots, usually at some distance from main stem, four cases widely scattered over root system, usually but two to three nodules per plant, one case thirty-five, two others forty-five, another 20. Seldom aggregated in masses.

Plot 6. Home mixed fertilizers, 60% bearing nodules. Here the nodules were of all sizes and locations, seldom large, seldom on main stem, as high as 110 on single plants, nodules then being small and segregated in masses on certain small rootlets. In other cases widely scattered. Root system rather less developed than in plot 5.

Plot 7. Stable manure, 4% only with nodules, plants so infested widely separated and each having but one nodule with a single exception where a plant had six large ones. Root system wonderfully developed, filling the entire mass of soil in upper six inches. Yield on this plot very heavy and color very dark green.

Plot 8. No fertilizer, but heavily rolled; 25% of plants bearing nodules, mostly large ones and near main stem, usually one to plant, occasionally several of smaller size.

Plot 9. Excess of nitrate of soda; 44% with nodules, universally small in size, and not on main stem, three to twenty small ones per plant.

Plot 10. Excess of phosphoric acid; 20% bearing nodules, all small and scattered with a single exception.

Plott 11. Excess of muriate of potash; 40% bearing nodules, half of them large and near main stem, remainder small and scattered.

Plot 12. Nitrogen plus phosphoric acid; 66% bearing nodules, practically all of them on side roots and distant from main stem, scattered not agglomerated in masses.

Plot 13. Nitrogen plus muriate of potash; 82% bearing nodules, nearly all small, one to forty-five per plant, sometimes scattered widely over root system, sometimes gathered in masses.

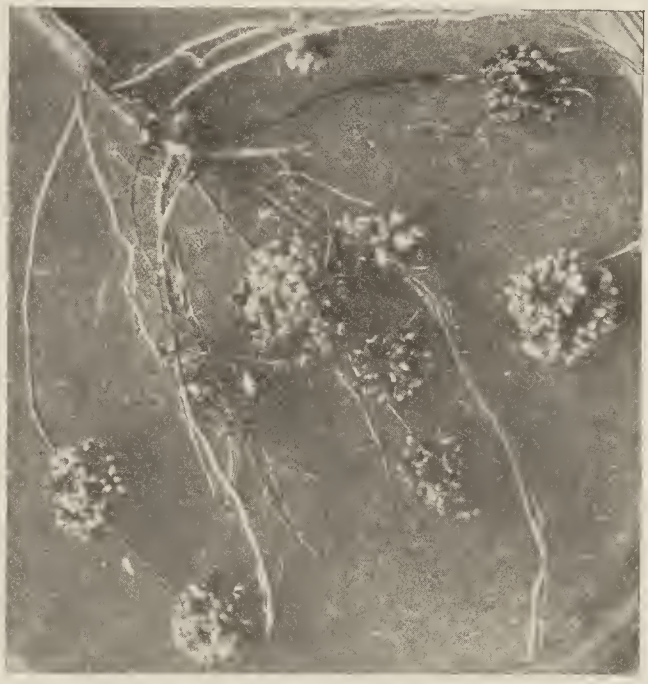
Plot 14. Phosphate plus muriate of potash; 98%, the number per plant running as high as forty-five, mainly on small roots away from main stem, sometimes on main stem, mostly small nodules.

Plot 15. No fertilizer; 82%, practically all small, some like fish eggs and widely scattered over root systems.

Plot 16. An abundance of lime; 20% bearing nodules.

Plot 17. One-half ton of wood ashes per acre; 10% bearing nodules.

No lesson could possibly be drawn from the experiment as results are not at all concordant.



Pea roots from Chatham Station.

REPORT ON THE INFLUENCE OF FERTILIZERS AND INOCULATION ON THE NUMBER OF NODULES ON THE ROOTS OF COWPEAS.

Twenty-two rows of cowpeas, seed not sterilized were sown north and south in the southeast corner of No. 6. The length of the rows was ten rods. The north two rods had an application of nitrate of soda at the rate of 150 pounds per acre. The second two rods from the north had an application of treated South Carolina rock at a rate sufficient to equal 200 pounds of fertilizer 8% phosphoric acid. The third two rods had an application of muriate of potash at the rate of 100 pounds per acre. The fourth two rods had wood ashes at the rate of 1,000 pounds per acre. The south two rods had lime, amount not stated.

The rows are numbered from the east. The first eleven were inoculated with soil from a plot bearing cowpeas last year with roots heavily infected.

In the table enclosed the nitrate of soda plot and the other four are given in order, each row by itself with the number of plants in the row and the average number of nodules per plant. The average is then given for the inoculated and uninoculated halves of the several plots.

NODULES ON THE ROOT OF COWPEAS.

NITRATE OF SODA.

Row.	*No. of plants.*	*Av. No. nodules.*	
1	69	30.78	
2	70	37.05	
3	66	35.98	
4	50	32.56	
5	57	36.01	
6	41	32.63	
7	48	33.31	
8	54	42.46	
9	42	22.13	
10	57	29.96	
11	76	32.14	
Average of inoculated			33.00
12	76	32.01	
13	62	34.50	
14	70	42.11	
15	56	42.12	
16	66	35.84	
17	58	36.32	
18	54	46.38	
19	68	44.86	
20	47	40.40	
21	44	55.42	
22	33	80.78	
Average of uninoculated			44.61

PHOSPHORIC ACID.

1	56	30.32	
2	61	29.16	
3	49	23.28	
4	45	28.91	
5	43	18.90	
6	33	17.44	
7	29	18.75	
8	47	21.06	
9	42	21.61	
10	31	23.61	
11	58	19.91	
Average of inoculated			22.99
12	67	25.55	
13	61	19.83	
14	62	20.90	
15	58	21.60	
16	48	23.81	
17	52	17.44	
18	53	20.39	
19	31	22.32	
20	29	23.65	
21	27	27.07	
22	27	18.66	
Average of uninoculated			21.93

MURIATE OF POTASH.

Row.	*No. of plants.*	*Av. No. nodules.*	
1	48	19.62	
2	47	18.02	
3	40	14.70	
4	11	8.27	
5	21	17.19	
6	25	4.84	
7	15	11.08	
8	8	13.12	
9	15	8.43	
10	28	3.46	
11	24	7.37	
Average of inoculated			11.37
12	35	5.54	
13	16	9.68	
14	25	5.48	
15	25	6.36	
16	27	7.07	
17	16	6.76	
18	20	13.70	
19	20	10.90	
20	12	16.66	
21	18	21.72	
22	16	14.00	
Average of uninoculated			10.71

WOOD ASHES.

1	50	17.34	
2	50	12.76	
3	42	10.95	
4	15	7.20	
5	35	6.62	
6	20	7.30	
7	22	5.95	
8	21	5.42	
9	25	7.08	
10	24	7.79	
11	26	4.92	
Average of inoculated			8.49
12	32	4.71	
13	33	4.15	
14	27	4.81	
15	28	4.39	
16	31	4.70	
17	18	3.50	
18	23	5.08	
19	16	4.43	
20	22	4.95	
21	17	8.29	
22	14	12.92	
Average of uninoculated			5.63
1	61	14.39	
2	50	17.38	
3	35	14.22	
4	31	20.51	
5	21	20.47	
6	21	6.66	
7	22	13.40	
8	20	7.80	
9	27	19.88	
10	31	22.35	
11	25	14.56	
Average of inoculated			15.57

Row.	*No. of plants.*	*Av. No. nodules.*
12	20	8.45
13	33	21.54
14	35	16.17
15	32	23.28
16	31	16.81
17	34	14.62
18	48	12.81
19	33	13.69
20	30	10.26
21	16	7.00
22	25	10.03
Average of uninoculated		12.24

On a strip of poor sandy soil, impoverished by six consecutive crops of sugar beets, the south third was sown to soy beans, the middle third to cowpeas and the north third to buckwheat. The next year strips of soy beans and cowpeas were sown north and south over the same area. In the fall the nodules were counted on the roots of the legumes.

Taking the soy beans first we found that where the soys followed soys, the number of nodules on ten plants was 991, where they followed cowpeas 108, and when they followed buckwheat 458. Again the form of the nodule and the style of distribution was entirely different over the three areas. Where the soys followed the soys the nodules were small and well scattered over the entire root system, seldom or never grouped into masses, but usually strung along the root at regular intervals. Where the soys followed the cowpeas the nodules were larger, much fewer in number and in shape resembling more nearly the nodule of the cowpea. Where following buckwheat the nodules were not unlike those where they followed soys.

In the case of the cowpeas, where they followed cowpeas, the number of nodules on ten plants was 448, where following buckwheat 229, and where following soys 210. Here too a tendency to smaller size was noted where the cowpeas followed the soys.

A later count, when the crops were riper confirmed these figures. In fact so conspicuous is the difference in form and distribution of the nodules on soy beans following soys and following cowpeas, that it was entirely possible to recognize at sight whether a given plant grew on one plot or on the other. Several trials resulted in not a single mistake.

Agricultural College.

THE PROTEID CONTENT OF WHEAT AS AN INDEX TO ITS BREAD MAKING QUALITIES.

A. J. PATTEN.

The proteid content of wheat in relation to its bread-making value has been studied by a number of investigators, and it is a matter of regret, that as yet, no more definite knowledge on this particular subject has been obtained.

While unquestionably the proteid content of wheat determines in no uncertain degree its value for bread-making purposes, still we are unable to say just why one particular flour is capable of producing bread of better quality than another flour when chemical and physical analyses show no differences in the two flours. For a clearer understanding of the subject it is necessary to know something of the several proteids found in wheat. They have been classified by Osborne and Voorhees briefly as follows:

(1) A globulin, soluble in salt solutions, and not coagulated at temperatures below 100° C.

(2) An albumin, which is coagulated at 52° C. and differs from animal albumin in several important respects.

(3) A proteose, precipitated (after removing the globulin by dialysis and the albumin by coagulation) by saturating the solution with common salt.

(4) Gliadin, soluble and dilute alcohol, and forming nearly half of the whole proteid matter of the kernel.

(5) Glutenin, insoluble in water, salt solutions and dilute alcohol, soluble, however, in very dilute acids and alkalies.

THE TOTAL PROTEID CONTENT IN RELATION TO THE BREAD-MAKING VALUE OF WHEATS AND FLOURS.

The proteid content of wheats varies quite materially. Some samples contain as low as 8 per cent, others as high as 18 or 20 per cent of total proteid material. For purposes of nutrition, those wheats containing a maximum amount of proteid material, provided it is in the best form for bread-making purposes, are most valuable. Unfortunately, however, it is very often true that wheats with a maximum proteid content produce flours of poor bread-making qualities.

Wheat containing a high percentage of proteid material may or may not produce flour with a correspondingly high proteid content, because the nitrogen of the wheat may be variously distributed; for example, in one sample, a majority of the nitrogen may be in the endosperm and less in the germ and bran, in which case the resultant flour would be relatively high in proteid material; on the other hand, a majority of the nitrogen may be in the offal parts and less in the endosperm or

floury portion and the result would be a flour of relatively low proteid content. The way in which the nitrogen of wheat is distributed is equally as important as the total amount. It should be the aim to secure wheat with a high proteid content in the endosperm rather than in the germ and bran.

Many attempts have been made to grade wheats and flours relative to their bread-making qualities according to their proteid content. This, however, results in erroneous conclusions, for the lower grades of flour, as red dog and first and second clear, would have a higher valuation than the patent grades. Neither can flours of the same grade be assigned comparative values on this basis, for two patent flours may have the same proteid content, yet possess altogether different bread-making values. The following table, prepared by Snyder, shows how little value can be placed on the total proteid determinations of flours as a guide to their bread-making qualities.

Grade of Flour.	Proteids per cent.	Commercial rank.
First patent	13.9	1
" "	13.34	2
" "	14.47	2
" "	13.17	1
Second "	14.15	5
" "	15.32	9
First "	12.63	1
Second "	14.44	9

CRUDE GLUTEN CONTENT IN RELATION TO THE BREAD-MAKING VALUE OF WHEATS AND FLOURS.

The insoluble proteids, gliadin and glutenin, together form the gluten of wheat. Crude gluten consists of the insoluble proteids together with more or less non-proteid material such as fiber, starch, etc. Crude gluten is easily obtained by kneading a dough from wheat flour or meal in a stream of cold water until the wash-water is free from turbidity.

The composition of the crude gluten would vary, depending upon the character of the flour used, as for example, with the low grade flours and whole wheat meals more of the non-proteid material and non-gluten proteids would be retained in the crude gluten than with the higher grades of flour such as the bakers and patent grades. Snyder has shown that the germ, bran and shorts of wheat and low grade flour contain from two to four times more water and salt-soluble proteids than the patent flours and states: "The process of milling results partly in a mechanical separation of the various proteids, the non-gluten proteids being recovered mainly in the by-products while the gluten proteids are recovered mainly in the flour. In the wheat from 80 to 85 per cent of the total nitrogen is in the form of gluten, while in the flour there is from 86 to 89 per cent in this form."

What was said in regard to the total proteid content of wheat and flour as an indication of its value for bread-making purposes, applies equally well to crude gluten, for there is no direct relation between the amount of crude gluten and the volume and texture of the loaf. A high gluten content does not necessarily mean a large loaf or good bread-

making qualities. A high gluten content is desirable, provided the gluten is of good quality.

The following table, prepared by Norton of South Dakota, shows this point very strikingly:

	Dry gluten per cent.	Rank as to texture and quality.
Five best straight durum wheat flours	16.94	2
Five poorest straight durum wheat flours	17.12	3
Five straight spring wheat flours	14.82	2
Two patent durum spring wheat flours	13.38	1
One patent spring wheat flour	10.38	1

The composition of the gluten is undoubtedly of more importance in determining the bread value of flour than the total gluten. Since gliadin and glutenin are the two principle proteids of wheat flour it is beleived by many that the ratio in which they exist in the flour determines largely its value for bread-making. Many attempts have been made to determine the ratio that gliadin should bear to gluten to give the best results. The work done along this line indicates that the gliadin-glutenin ratio varies considerably in wheats grown under similar conditions from year to year and that these variations are accompanied with only minor differences in the size of the loaf and general bread-making value of the flour. Snyder states that "the results available at the present time indicate that the percentage amount of gliadin (or proteid soluble in 70 per cent alcohol solution) in a flour is of more value than the gliadin-glutenin ratio," and suggests that flour for bread making purposes should contain about 11 per cent of total proteids, and that 55 to 65 per cent should be in the form of gliadin. These standards are in accord with the conclusions reached by Norton of South Dakota, and so far as my experience has gone, it seems to be true of Michigan wheats, though probably the average proteid content of our Michigan wheats and flours made therefrom is somewhat below the standard set by Snyder. Mr. Frank T. Shutt, Chemist of the Central Experiment Farm, Ottawa, Can., reports that in the Canadian wheats he found the percentage amount of gliadin to be somewhat less than 50. This suggests that either the Canadian wheats are lower in gliadin than are the wheats of our Northwest or possibly the gliadin is lacking in definite chemical composition.

Thus it is seen that no hard and fast rule can be laid down for determining the bread-making value of wheats and flours. The most useful of all the chemical tests are the total proteid determination (Nx5, 7) and the gliadin determination. We know that a flour with a very high or a very low amount of gliadin will produce poor bread, but in other than extreme cases, the actual bread-making value of a flour can only be ascertained by comparative bread-making tests. It is altogether probable that there is some other factor, as yet undiscovered, which has an important influence in determining the bread-making value of wheats and flours.

Agricultural College.

RAINFALL OF THE LAKE COUNTRY FOR THE LAST 25 YEARS.

MARK S. W. JEFFERSON.

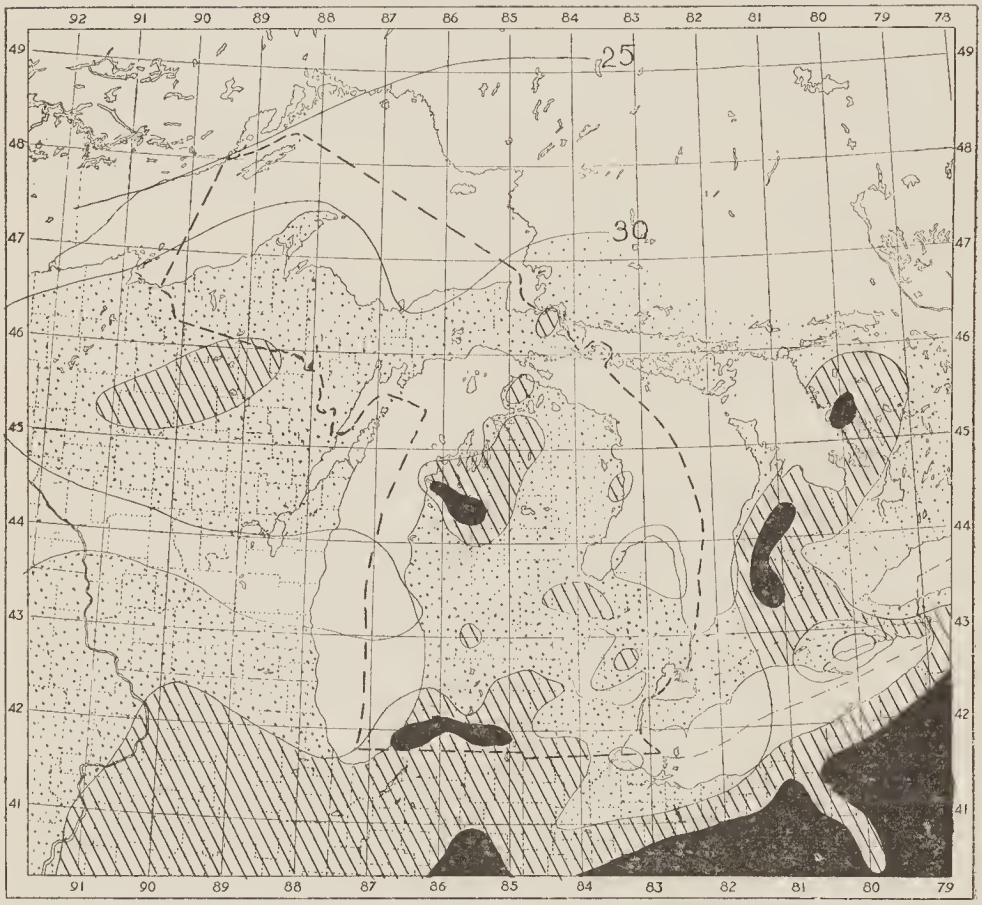


Fig. 1.—Rainfall of Lake country. 1880-1904. Black areas over 40 inches; lined, over 35; dotted over 30 and blank less than 30 inches per year.

The accompanying chart of mean precipitation about the Great Lakes (Fig. 1), is believed to be an advance on its predecessors in two respects, (1) it is based on several more years of observation, and (2) all incomplete records are reduced to the full epoch by the proportion between the precipitation for the partial and full periods at neighboring stations.

The epoch chosen is 1880 to 1904. It has been selected as a compromise between too long and too short a series. A series of rain observations is too short when the average of a longer period would have a value materially different. It is too long when few stations cover its full extent and its greater part comes before the beginning of many of the series of observations that must be made use of. Sixty-three of our 143 stations are of less than fifteen years length of observation, most of them for the last ten or fifteen years only, and the observations previous to 1880 at the few stations where any were made in the region are unsuitable for comparison with these recent data.

Mr. A. J. Henry* says: "The average variation of a twenty-five year period is about 5 per cent," meaning that the single year's observation will, on the average, differ by that amount from the mean of the 25.

Of the 143 stations from which data have been used, eighty-three are in Michigan, and sixty in neighboring territory, furnished by the courtesy of the United States Weather Bureau, the State Weather services, especially that of Michigan, and the Meteorological Service of Canada. The data are accepted as furnished since an adequate study of the original observations could be made only within the services in charge of them. The discussion by Prof. Henry at p. 9 of Bulletin D, states that the registers of the roof gages of the Weather Bureau stations probably fall short of the true precipitation by 5 or 10 per cent. It might be thought that the eighteen records from such stations included in our list would reveal this defect on mapping them beside records from volunteer observers in Michigan and other states. No tendency of the sort, however, appears in this region. As to the rain measurements of volunteer observers, it is easy to understand that there are great possibilities for inaccuracy in the conditions of their work and occasional examples come under one's eye of what should not be done in the way of scientific observation, yet the discussion of their results shows that these unpaid workers have deserved the greatest praise for careful and unremitting attention to a task that no one who has not carried on meteorological observations through fair weather and foul, through work days and holidays, can fully appreciate.

The following little table shows the grouping of the observation stations by years of record:

Stations.	Years of record.
25	25
19	20-25
26	15-19
25	10-14
48	5-9

The averages for the complete records (1880-1904) were entered directly on a blank chart. The corrections applied to other records are based on the fact that there are years and groups of years of heavier, others of lighter rainfall than the average. Thus at the twenty-one *complete* stations the average rainfall of the five years, 1880-1884, was almost invariably 10 to 15 per cent greater than the average of the whole twenty-five years, as is seen in the table below.

* Weather Bureau Bulletin D, Rainfall of the U. S., p. 320.

RAINFALL IN THE GREAT LAKE COUNTRY FOR THE TWENTY-FIVE YEARS, 1880 TO 1904, BY FIVE YEAR MEANS. UNITY ON EACH LINE IS THE MEAN OF THE TWENTY-FIVE YEARS FOR THAT PLACE.

	1880-4.	1885-9.	1890-4.	1895-9.	1900-4.
Marquette	1.12	0.90	1.01	0.95	1.03
Alpena	1.25	1.06	0.97	0.90	0.81
Port Huron	1.18	0.88	1.06	0.95	0.93
Lansing	1.20	0.89	0.97	0.94	1.03
Detroit	1.16	0.84	1.01	0.96	1.04
Wauseon, O	1.03	0.86	1.06	1.07	1.01
Toledo	1.16	0.95	0.93	0.91	1.00
Duluth	1.21	0.99	0.96	0.92	0.90
Davenport, Ia	1.18	1.04	0.91	0.94	0.93
Keokuk	1.09	0.95	0.88	1.12	0.97
La Crosse	1.18	0.87	0.97	0.89	1.09
Fort Madison	1.12	0.86	0.90	1.12	0.97
Dubuque	1.26	0.95	1.01	0.92	0.88
Clinton	1.17	0.97	0.95	0.95	0.98
Peoria	1.13	0.91	0.88	1.03	1.06
Port Arthur	1.07	1.00	0.89	1.04	0.98
Milwaukee	1.06	1.01	1.05	0.94	0.95
Chicago	1.21	1.02	0.92	0.92	0.89
Manitowoc	(1.23)	0.99	0.96	0.81	0.99
Escanaba	1.25	1.22	(0.96)	1.13	0.94
Saugeen	1.00	0.98	1.04	0.96	0.98
Mean	1.15	0.96	0.97	0.97	0.97

Had we no record for Marquette for the years 1880-1884, it is evident that since those years were unusually wet ones, the average for the years since 1884 would be too small, 97 per cent in fact of the average for the whole period. This will be set right by multiplying the average for the twenty years by 100/97ths. There is enough consistence in the figures of the table to show the need and value of this reduction to a uniform period, enough of irregularity to show that after reduction we have not the real value of the precipitation for the twenty-five years, but a value that in most cases is nearer to it than the uncorrected mean is.

To satisfy any desire to know what the result would have been had the straight means of the observations been used, I have placed them on a blank and reproduce the resulting isohyetals in Fig. 2. It serves at any rate to show that the changes introduced by the system of corrections, have been very moderate in amount, and at the same time distinctly make for consistency and clearness. The method of reduction is shown by the following details for Grantsburg, Wis., the first place on the list. There are twelve years of measurements at Grantsburg, with an average rainfall of 32.77 inches for those years. What we need is the average fall for the twenty-five years, 1880 to 1904. At La Crosse, which was selected as station for reference, the average for the same twelve years, column headed *n* years, is 29.54, for the whole twenty-five years 29.86. At La Crosse, therefore, the whole period average was $\frac{2986}{2954}$ of that of the twelve years. We assume the same to be true at Grantsburg and multiply the value 32.77 by that fraction, giving $\frac{2986}{2954} \times 32.77 = 33.1$, the reduced value. Latitude and longitude is added to facilitate identification of stations on the map. The eleva-

FIG. 2.—Rainfall chart with data merely averaged regardless of length of observation series. Shades 40, 35 and 30 inches per year.

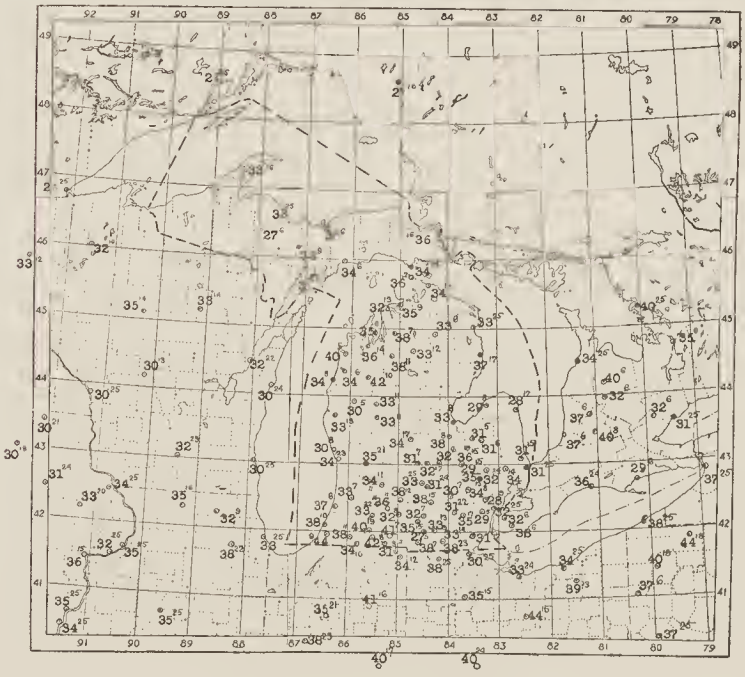


FIG. 3.—Heavy figures show mean rainfall for 1880–1904, all series reduced to full period. Small numbers give the number of years of observation.

tions given are as near as can be learned those of the gages above sea level. At Weather Bureau stations therefore the ground surface is one or two hundred feet lower. Such stations are marked WB in the margin of the list.

Fig. 3 has been prepared to show at a glance the rainfall at each station made use of, thus reduced to uniform epoch, as well as the length of the series of observations by the small number written alongside. This and the table of data that follows give the reader all the facts used in preparing our chart of rainfall. How the isohyetals or lines of equal rainfall have been drawn will be best made out by inspection of Fig. 3. In the main the figures have been closely followed with some slight modification for probable error of the series of different lengths. This matter of the probable error of the mean of a series of observations of precipitation of any given length has not yet been sufficiently studied. There are some considerations cited in Hann's Meteorologie at p. 324, from which it appears that a rainfall series of ten years may be liable to an error of about five inches in our neighborhood, one of twenty-five years about two inches. The accordance of neighboring stations may greatly reduce their liability to error.

LIST OF STATIONS.

No.	Station.	Long.	Lat.	Elevation.	No. of years.	Average annual precipitation.	Reference station.	Averages at reference station.		Mean annual precipitation for 1880-1904.
								25 years.	n. years.	
1	Grantsburg, Wis.	92.7	45.8	1,100	12	*32.77*	La Crosse.	29.86	29.54	33.1
2	Charles City, Ia.	92.7	43.1	1,005	18	*30.65*	La Crosse.	29.86	30.37	30.1
3	Duluth, Minn.	92.1	46.8	702	25	.....	.....	.....	.....	28.4 WB
4	Cresco, Ia.	92.1	43.4	1,300	21	*30.54*	La Crosse.	29.86	30.37	30.0
5	Independence, Ia.	91.9	42.5	921	24	*30.77*	Dubuque.	33.65	33.73	30.7
6	Hayward, Wis.	91.5	46.	1,197	10	*30.77*	La Crosse.	29.86	28.83	31.5
7	Keokuk, Ia.	91.4	40.4	613	25	.....	.....	.....	.....	34.3 WB
8	La Crosse, Wis.	91.3	43.8	720	25	.....	.....	.....	.....	29.9 WB
9	Fort Madison, Ia.	91.3	40.6	522	25	.....	.....	.....	.....	35.4
10	Monticello, Ia.	91.2	42.2	925	20	*33.18*	Dubuque.	33.65	34.22	32.6
11	Muscatine, Ia.	91.0	41.4	554	15	*37.03*	Davenport.	32.16	33.58	35.5
12	Dubuque, Ia.	90.7	42.5	698	25	.....	.....	.....	.....	33.5 WB
13	Davenport, Ia.	90.6	41.5	613	25	.....	.....	.....	.....	32.2 WB
14	Medford, Wis.	90.3	45.2	1,420	14	*34.41*	La Crosse.	29.86	29.39	35.0
15	Clinton, Ia.	90.3	41.8	593	25	.....	.....	.....	.....	34.7
16	Meadow Valley, Wis.	90.2	44.3	974	13	*29.16*	La Crosse.	29.86	29.33	29.7
17	Peoria, Ill.	89.6	40.7	519	25	.....	.....	.....	.....	35.3
18	Madison, Wis.	89.4	43.1	955	23	*32.03*	La Crosse.	29.86	29.67	32.2
19	Port Arthur, Ont.	89.3	48.4	644	25	.....	.....	.....	.....	23.6
20	Koepenick, Wis.	89.2	45.3	1,683	14	*32.12*	La Crosse.	29.86	28.99	33.1
21	Winnebago, Ill.	89.2	42.3	900	16	*33.09*	Davenport.	32.16	30.33	35.1
22	Marengo, Ill.	88.6	42.3	819	9	*35.96*	Chicago.	32.67	37.16	31.6
23	Calumet.	88.4	47.3	1,202	16	*32.58*	Marquette.	33.10	32.70	33.0
24	Aurora Ill.	88.3	41.7	676	22	*38.18*	Chicago.	32.67	32.39	33.5
25	Green Bay, Wis.	88.	44.5	616	18	*30.91*	Milwaukee.	29.74	29.00	31.7
26	Humboldt.	87.9	46.5	1,522	6	*25.89*	Marquette.	33.10	31.71	27.0
27	Milwaukee, Wis.	87.9	43.	673	25	.....	.....	.....	.....	29.7 WB
28	Manitowoc, Wis.	87.6	44.2	616	24	*30.38*	Milwaukee.	29.74	29.73	30.4
29	Chicago, Ill.	87.6	44.3	824	25	.....	.....	.....	.....	32.7 WB
30	Marquette.	87.4	46.6	734	25	.....	.....	.....	.....	33.4 WB
31	Lathrop.	87.2	46.2	1,142	9	*32.32*	Marquette.	33.10	32.02	33.4
32	Escanaba.	87.1	45.7	612	22	*30.60*	Marquette.	33.10	33.15	30.6 WB
33	Lafayette, Ind.	86.9	40.5	661	23	*37.25*	Chicago.	32.67	31.97	33.1
34	Wetmore.	86.7	46.4	853	6	*30.11*	Marquette.	33.10	33.22	30.0
35	St. Joseph.	86.5	42.2	590	10	*35.55*	Chicago.	32.67	30.38	33.2
36	Manistee.	86.3	44.3	600	8	*32.15*	Manitowoc.	30.35	28.73	34.0
37	Hart.	86.3	43.7	695	13	*31.48*	Lansing.	33.15	31.52	33.1
38	Muskegon.	86.3	43.2	593	8	*30.03*	Lansing.	33.15	32.65	30.5
39	Berrien Springs.	86.3	41.9	671	9	*39.77*	Chicago.	32.67	29.28	44.4
40	Logansport, Ind.	86.3	40.7	620	21	*35.72*	Chicago.	32.67	33.17	35.2
41	Manistique.	86.2	46.	613	6	*33.15*	Marquette.	33.10	32.62	33.6
42	Benzonia.	86.2	44.6	606	5	*34.53*	Alpena.	32.79	27.97	40.5
43	Bear Lake.	86.2	44.4	(720)	6	*33.31*	Manitowoc.	30.38	30.07	33.5
44	Grand Haven.	86.2	43.1	628	23	*34.07*	Lansing.	33.15	33.26	34.1
45	South Haven.	86.2	42.4	582	6	*32.28*	Chicago.	32.67	28.59	37.0
46	Vandalia.	85.9	41.9	877	11	*35.86*	Chicago.	32.67	30.66	38.2
47	Baldwin.	85.8	43.9	837	5	*29.37*	Lansing.	33.15	32.82	29.7
48	Allegan.	85.8	42.5	707	7	*30.93*	Chicago.	32.67	29.88	33.3
49	Mottville.	85.8	41.7	(850)	10	*31.86*	Chicago.	32.67	30.31	34.3
50	Traverse City.	85.7	44.7	600	14	*36.13*	Alpena.	32.79	32.93	36.0
51	Grand Rapids.	85.7	43.0	646	21	*35.27*	Lansing.	33.15	32.99	35.4
52	Boon.	85.6	44.3	1,387	10	*37.15*	Manitowoc.	30.38	26.92	41.9
53	Parkville.	85.6	42.	(850)	19	*42.13*	Chicago.	32.67	34.01	40.5
54	Huntington, Ind.	85.6	40.9	741	16	*37.69*	Chicago.	32.67	30.35	40.6
55	Old Mission.	85.5	45.0	(600)	6	*29.29*	Alpena.	32.79	27.59	34.8
56	Reed City.	85.5	43.9	(1,033)	11	*36.36*	Lansing.	33.15	36.86	32.7
57	Kalamazoo.	85.5	42.3	760	22	*38.47*	Lansing.	33.15	33.29	33.3
58	Big Rapids.	85.5	43.7	1,000	8	*33.18*	Lansing.	33.15	32.65	33.2
59	Wasepi.	85.5	41.8	857	8	*36.66*	Chicago.	32.67	28.88	41.6
60	Charlevoix.	85.3	45.3	589	13	*30.35*	Alpena.	32.79	31.46	31.7

STATIONS.—*Continued.*

No.	Station.	Long.	Lat.	Elevation.	No. of years.	Average annual precipitation.	Reference station.	Averages at reference station.		Mean annual precipitation for 1880–1904.
								25 years.	n. years.	
61	Hastings	85.3	42.7	790	11	*33.65*	Chicago	32.67	31.87	34.5
62	White River, Ont.	85.2	48.6	1,147	16	*25.66*	Port Arthur	23.56	23.06	26.3
63	Ivan	85.2	44.7	1,200	11	*32.28*	Alpena	32.79	28.52	37.7
64	Bronson	85.2	41.8	926	8	*29.22*	Chicago	32.67	31.21	30.6
65	Farmland, Ind.	85.2	40.2	1,101	17	*37.24*	Chicago	32.67	30.46	39.9
66	Mancelona	85.1	44.9	1,117	7	*34.41*	Alpena	32.79	29.34	38.5
67	Battle Creek	85.1	42.3	823	10	*33.62*	Chicago	32.67	30.86	35.6
68	Petoskey	85.	45.3	662	9	*32.52*	Alpena	32.79	30.20	35.3
69	North Marshall	85.0	42.3	896	8	*31.58*	Lansing	33.15	31.74	32.2
70	Coldwater	85.1	41.9	982	7	*36.78*	Chicago	32.67	29.32	41.0
71	Angola, Ind.	85.0	41.6	1,052	19	*38.63*	Chicago	32.67	30.87	40.9
72	Olivet	84.9	42.5	885	12	*36.38*	Lansing	33.15	31.68	33.1
73	Grayling	84.8	44.7	1,134	12	*28.96*	Alpena	32.79	28.62	33.0
74	St. Ignace	84.7	45.9	589	13	*30.60*	Alpena	32.79	29.61	33.0
75	Mackinaw City	84.7	45.7	596	7	*35.50*	Marquette	33.10	32.87	35.8
76	Alma	84.7	43.4	773	17	*32.09*	Lansing	33.15	31.15	34.2
77	Hillsdale	84.7	41.9	1,239	7	*37.12*	Toledo	30.47	29.62	38.2
78	St. Johns	84.6	43.	766	7	*27.65*	Lansing	33.15	28.90	31.0
79	Agricultural College	84.6	42.8	(820)	24	*31.65*	Lansing	33.15	33.40	30.7
80	Hanover	84.6	42.1	1,114	15	*33.37*	Lansing	33.15	31.05	34.8
81	Cheboygan	84.5	45.6	604	12	*30.29*	Alpena	32.79	29.39	33.8
82	Sault Ste. Marie	84.4	46.5	642	16	*32.12*	Alpena	32.79	29.53	35.6
83	Ovid	84.2	43.	734	17	*30.01*	Lansing	33.15	31.15	31.9
84	Lansing	84.4	42.7	841	25					33.2
85	Jackson	84.4	42.3	925	7	*31.25*	Lansing	33.15	32.26	32.1
86	Somerset	84.4	42.0	(1,100)	5	*29.11*	Wauseon	38.42	40.92	27.3
87	Lewiston	84.3	44.8	(1,200)	6	*30.12*	Alpena	32.79	29.91	33.0
88	Fitchburg	84.3	42.4	981	15	*36.31*	Lansing	33.15	31.45	33.3
89	Madison	84.3	42.0	955	13	*31.38*	Adrian	38.11	36.59	32.7
90	Owosso	84.2	43.1	755	6	*32.66*	Lansing	33.15	34.18	31.7
91	Wauseon, O.	84.2	41.5	800	25					38.4
92	Adrian	84.1	41.9	810	23	*38.53*	Wauseon	38.42	38.74	38.2
93	Saginaw, W.	84.0	43.4	590	8	*34.22*	Port Huron	30.68	29.23	33.4
94	Clinton	84.0	42.1	832	14	*31.84*	Toledo	30.47	29.47	32.9
95	Bay City	83.9	43.6	593	8	*31.70*	Port Huron	30.68	29.23	33.2
96	Howell	83.9	42.6	921	7	*29.00*	Lansing	33.15	31.51	29.8
97	Ann Arbor	83.8	42.3	930	22	*31.70*	Detroit	31.85	32.12	31.4
98	Arbela	83.7	43.3	728	15	*34.25*	Port Huron	30.68	29.42	35.9
99	Flint	83.7	43.0	726	15	*28.08*	Lansing	33.15	31.29	29.1
100	Ypsilanti	83.7	42.3	736	17	*33.91*	Detroit	31.85	31.07	34.3
101	Vassar	83.6	43.3	651	5	*30.27*	Port Huron	30.68	30.18	30.8
102	Highland	83.6	42.3	1,006	8	*32.14*	Lansing	33.15	31.80	33.5
103	Toledo, O.	83.6	41.7	674	25					30.5 WB
104	Findlay, O.	83.6	41.1	782	15	*36.22*	Wauseon	38.42	39.91	34.9
105	North Lewisburg, O.	83.6	40.2	1,095	24	*40.01*	Wauseon	38.42	28.39	40.0
106	Alpena	83.5	45.1	609	25					32.8 WB
107	Grape	83.5	41.9	625	17	*29.36*	Toledo	30.47	28.61	31.3
108	Harrisville	83.3	44.7	616	17	*34.82*	Alpena	32.79	30.64	37.3
109	Hayes	83.3	43.9	620	8	*28.51*	Port Huron	30.68	29.37	29.4
110	Mayville	83.3	43.3	916	6	*32.03*	Port Huron	30.68	31.67	31.0
111	Ball Mountain	83.3	42.8	932	13	*32.80*	Lansing	33.15	32.07	34.9
112	Eloise	83.3	42.3	640	5	*28.70*	Detroit	31.85	31.37	29.1
113	Thornville	83.2	42.9	975	24	*31.47*	Lansing	33.15	33.02	31.6
114	Birmingham	83.2	42.5	660	9	*27.50*	Lansing	33.15	32.28	28.2
115	Detroit	83.1	42.3	724	25					31.8 WB
116	Berlin	82.9	42.9	686	14	*31.35*	Port Huron	30.68	28.74	33.5
117	Harbor Beach	82.7	43.8	635	17	*26.77*	Port Huron	30.68	29.26	28.1
118	Sandusky, O.	82.7	41.4	629	24	*33.27*	Toledo	30.47	30.31	33.4 WB
119	Jeddo	82.6	43.2	667	15	*30.10*	Port Huron	30.68	30.05	30.7
120	Mansfield, O.	82.6	40.8	1,154	15	*42.99*	Cleveland	34.17	33.42	44.0

STATIONS.—*Concluded.*

No.	Station.	Long.	Lat.	Elevation.	No. of years.	Average annual precipitation.	Reference station.	Averages at reference station.		Mean annual precipitation for 1880–1904.
								25 years.	n. years.	
121	Port Huron	82.5	43.0	639	25	.....	.....	.....	.....	30.7 WB
122	Hudson, O	81.5	41.3	1,053	13	*37.92*	Cleveland	34.17	32.82	39.5
123	Cleveland, O	81.7	41.5	627	25	.....	.....	.....	.....	34.2 WB
124	Saugeen, Ont	81.3	44.5	656	25	.....	.....	.....	.....	34.2
125	Port Stanley, Ont	81.2	42.7	579	24	*35.33*	Erie, Pa	38.04	37.76	35.6
126	Stratford, Ont	81.0	43.4	1,190	8	*40.59*	Saugeen	34.22	34.86	37.2
127	Newcastle, Pa	80.3	41.0	800	6	*38.50*	Pittsburg	36.83	38.14	37.2
128	Erie, Pa	80.1	42.1	600	25	.....	.....	.....	.....	38.0 WB
129	Parry Sound, Ont	80.0	45.3	635	25	.....	.....	.....	.....	39.7
130	Pittsburg, Pa	80.	40.5	842	25	.....	.....	.....	.....	36.3 WB
131	Franklin, Pa	79.8	41.4	955	18	*40.87*	Erie	38.04	38.90	40.0
132	Toronto, Ont	79.4	43.7	260	25	.....	.....	.....	.....	31.1
133	Warren, Pa	79.2	41.9	1,137	18	*43.42*	Erie	38.04	37.15	44.5
134	Buffalo, N. Y	78.9	42.9	690	25	.....	.....	.....	.....	37.4 WB
135	Cottam, Ont	82.7	42.1	606	6	*34.50*	Detroit	31.85	28.94	33.0
136	Maidstone, Ont	82.9	42.2	627	6	*28.97*	Detroit	31.85	28.94	31.9
137	Egremont, Ont	80.8	43.9	.....	6	*33.56*	Saugeen	34.22	37.06	31.0
138	Durham, Ont	80.7	44.2	.....	6	*43.08*	Saugeen	34.22	37.06	39.3
139	Georgetown, Ont	80.0	43.6	850	6	*31.77*	Toronto	31.11	30.63	32.3
140	Orillia, Ont	79.4	44.6	775	6	*31.99*	Parry Sound	39.72	37.13	34.7
141	Zurich, Ont	81.7	43.5	.....	6	*36.36*	Port Huron	30.68	29.83	36.5
142	Listowell, Ont	80.9	43.7	1,260	6	*38.75*	Saugeen	34.22	37.06	35.3
143	Port Dover, Ont	80.2	42.8	636	6	*32.73*	Erie	38.04	42.83	29.1

If we glance at Fig. 4 we shall see that the heavy rains occur not merely to southeast of the Lakes, as Harrington pointed out in 1894, but rather where strong slopes lie in this position. See especially in Ontario east of Lake Huron, in the lower peninsula of Michigan, between Lake Michigan and the strong northwest-facing slopes north and south of the Saginaw valley, in the highlands along the boundary of northern Wisconsin and the upper peninsula, and in the strong ascent from Lake Erie to the Allegheny plateau. In this latter region it is interesting to note the slightly diminished precipitation in the valleys, as at Pittsburg and Newcastle. Very remarkable is the V of less than thirty inches—four stations—northwest of Detroit and coinciding with the lower land among the hills that culminate at Ball Mt., in Oakland county. H. V. Payne, 1889 (?) pointed out this effect of the Ontario elevation in extracting greater rainfall from the winds that prevail here from the west. Fig. 1 shows it to be present throughout the whole region. All slopes to leeward of the Lakes get heavier rainfall. Shores to windward of the Lakes are equally characterized by light precipitation, as at Milwaukee, the thumb of Michigan and Toledo, the west end of Lake Ontario and north of the east end of Lake Erie. Increase of precipitation with elevation is familiar to students of rainfall in all situations where slopes oblige rain-bringing winds to ascend. Prof. Hann recommends it as a desirable improvement in drawing charts of the monthly rainfall in the United States that base maps with thousand-foot contours be used and some regard had to these in drawing isohyetals.

Our rainfall is provoked by ascensional movement within cyclones or in thunderstorms within cyclonic areas. Easterly and southerly winds

prevail during our rains over all the east part of the United States, because other winds come to us from regions ill-supplied with moisture in comparison with the air over Atlantic and Gulf. It is for this reason of course that the rains augment pretty steadily as the eastern and southern coast is approached from the west. The vapor condensed here rose originally from the ocean. The Lakes are mere pools of this rain condensed from vapors of marine origin, lingering in hollows on their way to the sea. The widening of the belt of thirty-inch rainfall that occurs near the Lakes, implies at most an addition of five or six inches by reevaporation from the surface of the Lakes themselves.

FIG. 4.—Dotted areas above 1,000 feet; lined areas above 1,500 above sea level.

The somewhat high rainfall on the east coast north of Saginaw Bay is the record of the single station, Harrisville. It is not apparent why it should be large. It would be prudent to examine the gage and its exposure.

It was shown by the table, at page 3, that the rainfall at neighboring places was roughly sympathetic without closeness of correspondence. Neighboring places have heavy rains usually in the same years and so also their light rains. The failures in this correspondence are as interesting as the agreements. An instance was found in reducing the sixteen-year record of Sault Ste. Marie by using Marquette and Alpena as alternative reference stations. During those first nine years, Marquette's rainfall was about the same as for the average of the entire twenty-five years. Alpena, on the contrary, had fairly 15 per cent more

than its average then. So the Sault had quite different values when reduced for epoch with reference to these two stations respectively, 32.5 inches by Marquette and 35.65 inches by Alpena. The distances are to Marquette 144 miles, to Alpena eighty-two. The list has been looked over for other similar cases. No differences so great were found. The fact is Marquette and Alpena are in regions contrasted in rain conditions. It is not possible to say beforehand to which group the Sault really belongs, though after trying both ways preference has been given to Alpena. Although the difference amounted to only three inches

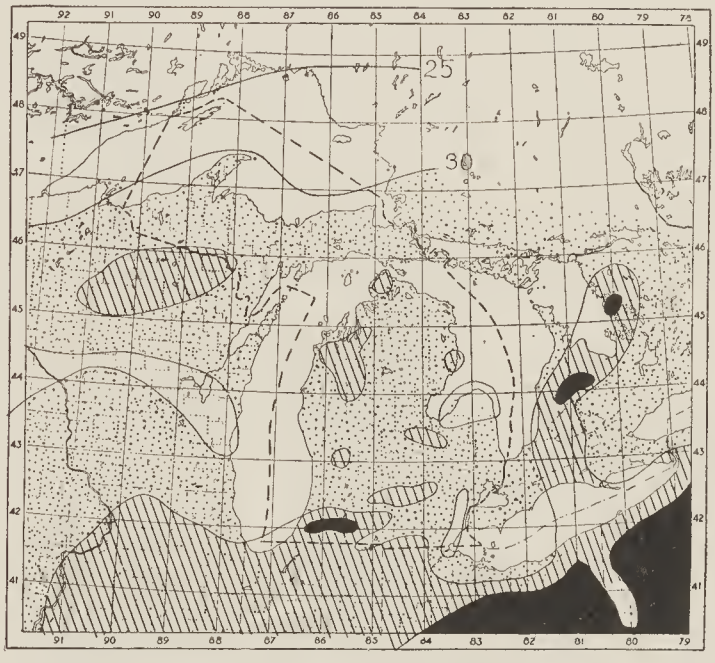


FIG. 5.—Rainfall chart with incomplete series of observations reduced by six groups of reduction stations. Shades 40, 35 and 30 inches.

even in this case it was thought prudent to eliminate local influences that might be peculiar by a new reduction of all the broken series of observations with reference to the means of six groups of selected stations.

1. Marquette, Parry Sound, Manitowoc, Alpena, Saugeen.
2. Duluth, Marquette, La Crosse, Manitowoc.
3. Port Huron, Lansing, Detroit, Wauseon, Chicago.
4. Milwaukee, Chicago, Dubuque.
5. Saugeen, Port Huron, Toronto.
6. Erie, Cleveland, Pittsburg.

Fig. 5 shows the result of this reduction in map form. It only serves to confirm our faith in a reduction by single near stations as used for Fig. 1. No essential of Fig. 1 is changed, but the response

to topographic influences is less sharp. The fact is rainfall is subject to large and irregular variations even within one locality. New Orleans had five rain gages exposed at different points within her limits, under one management, for the years 1895 to 1904. The records were published in the Monthly Weather Review for May, 1905. The greatest distance between gages is six miles: The following are the annual values for the five stations:

	Dublin.	Park.	Jefferson.	Hall.	London.
1895	62.99	66.31	65.59	56.61	59.74
1896	51.60	52.31	54.37	51.46	61.18
1897	54.54	50.10	47.74	46.66	53.93
1898	60.43	63.69	58.77	54.57	55.41
1899	39.58	41.32	38.14	33.95	43.03
1900	67.51	66.44	62.73	57.99	63.66
1901	54.58	55.65	50.46	49.48	57.54
1902	40.18	38.13	38.33	37.04	38.83
1903	57.09	47.36	45.13	51.39	51.96
1904	39.50	38.66	37.22	37.31	38.02
Mean	52.80	52.00	49.85	47.65	52.33

FIG. 6.—Rainfall chart by U. S. Weather Bureau 1902. Shades are 40, 35 and 30 inches.

The elevation of the gages above the ground is not given, but that on the City Hall is doubtless on the roof, perhaps 100 feet from the street. That at the Park is doubtless near the ground. The figures, both average and individual, agree well with this supposition, the roof station having the usual defect of rainfall. To judge from the figures, Dublin and London are also surface stations, but it is observed that while Dublin, Park and London show close agreement in the ten-year average, in the single years they differ widely and in different senses in different years. We need not be surprised then to find an inch or two of difference even in the means of observations at stations a hun-

FIG. 7.—Rainfall map by C. A. Schneider, 1900.

dred or more miles apart and having very different exposure to the winds. I believe interesting results will come of a better examination of the winds prevailing during actual rainfall at various stations than has yet been made. The increment of rainfall on northwesterly slopes can hardly be due to other than westerly or northwesterly winds. I have some evidence of this at Saugeen in an unusual proportion of heavy rains with northwest winds. In any year when the cyclonic paths run south, northwest winds should be frequent in this region. All the slopes to lee of Lakes are likely to get larger rain under these circumstances, but the slopes to windward of the Lakes as at Detroit should suffer a distinct defect. Or perhaps there will be a defect at all stations of the region in such years mitigated on leeward shores by some compensating increase in precipitation due to northwest winds. A compari-

son of the five-year averages at east-facing Alpena and west-facing Saugeen on Lake Huron, illustrates this pretty well. Perhaps the chief inference to be drawn is that in selecting reference stations for the reduction of imperfect series similarity of situation will be an important guide.

Fig. 6 reproduces a portion of the latest rainfall chart of the United States, made by Mr. Henry in 1902, and published in the Monthly Weather Review of April of the year. It is the first such chart I think that our Weather Bureau has published in which some attempt is made to reduce imperfect series to the epoch adopted for study "by a process of extrapolation." It was only done in some cases however, though in Europe it is the accepted method of constructing isohyetal maps. The period of this chart is 1870 to 1901. It has as good an agreement with our chart as could be expected from the employment of twenty Michigan stations where we are using 84. The stations employed are of course the best ones.

Fig. 7 reproduces Section Director Schneider's map of 1900. I have seen no statement of the plan on which it was drawn, but internal evidence suggests that short series have not been reduced to agreement with their longer term neighbors. The map cannot fairly be compared with Fig. 1, which has the advantage of four more years time of observation, a great advantage indeed in a state where so many of the series of observations began in 1897.

On the pages that follow are reproduced the original data used. The number printed at the head of each column refers to the number in the list of stations above.

ANNUAL PRECIPITATION.

Years.	92 Adrian.	79 Agricultural College.	48 Allegan.	76 Alma.	106 Alpena.	71 Angola, Ind.	97 Ann Arbor.	98 Arbela.	24 Aurora, Ill.	67 Battle Creek.	Years.
1880	43.09	43.98	.....	.....	43.63	.....	44.25	.....	44.49	.....	1880
1881	63.31	34.66	.....	.....	45.61	.....	39.97	.....	45.75	.....	1881
1882	46.46	32.88	.....	.....	45.10	.....	34.92	.....	.....	.....	1882
1883	43.30	48.36	.....	.....	35.32	.....	.....	.....	46.51	.....	1883
1884	36.50	36.28	.....	.....	35.53	.....	.....	.....	36.76	.....	1884
1885	41.33	35.00	.....	.....	34.71	42.22	35.20	.....	39.50	26.98	1885
1886	.....	29.95	.....	.....	40.12	.....	27.59	.....	32.46	.....	1886
1887	38.28	31.10	.....	.....	37.88	33.75	28.63	.....	36.16	.....	1887
1888	30.70	26.56	.....	27.06	29.36	34.64	27.23	21.02	34.10	.....	1888
1889	27.89	23.78	.....	26.50	31.32	32.86	24.85	.....	.....	.....	1889
1890	45.06	31.91	38.37	34.32	31.35	40.15	34.35	30.56	37.70	.....	1890
1891	40.20	24.78	.....	34.75	31.61	37.67	.....	.....	38.09	.....	1891
1892	51.89	29.92	32.23	36.21	32.15	40.42	29.93	33.43	47.96	.....	1892
1893	38.98	31.29	37.37	37.00	33.35	38.65	39.12	40.33	.....	.....	1893
1894	38.47	19.30	29.22	28.81	30.88	30.87	25.64	22.12	29.05	.....	1894
1895	27.77	22.80	26.16	24.41	21.59	31.75	22.75	29.07	31.86	.....	1895
1896	38.14	33.22	.....	31.46	30.14	52.02	31.17	28.73	39.25	39.88	1896
1897	28.09	33.61	.....	35.33	32.59	34.97	32.51	39.23	38.15	31.39	1897
1898	39.24	32.42	.....	36.24	34.07	45.98	33.00	33.56	46.60	32.38	1898
1899	35.75	23.67	.....	26.84	29.93	35.36	25.86	35.73	32.79	33.49	1899
1900	33.88	31.62	.....	31.18	23.03	42.48	28.58	41.34	30.81	37.02	1900
1901	24.92	32.49	19.01	27.57	25.23	40.60	26.09	25.17	22.21	31.78	1901
1902	32.72	38.50	.....	37.57	29.02	40.56	41.55	46.84	50.98	41.43	1902
1903	.....	31.53	34.15	38.30	31.54	39.26	35.95	47.28	41.54	32.92	1903
1904	38.18	.....	.....	31.92	24.68	39.76	28.19	39.37	37.16	28.97	1904

Years.	111 Ball Mountain.	95 Bay City.	43 Bear Lake.	42 Benzonia.	116 Berlin.	39 Berrien Springs.	58 Big Rapids.	114 Birmingham.	52 Boon.	64 Bronson.	Years.
1880	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1880
1881	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1881
1882	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1882
1883	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1883
1884	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1884
1885	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1885
1886	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1886
1887	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1887
1888	.....	.....	36.39	37.69	28.81	.....	.....	27.31	.....	24.47	1888
1889	.....	.....	31.36	.....	22.93	.....	.....	.....	.....	26.88	1889
1890	38.78	.....	32.69	.....	44.39	.....	.....	.....	.....	35.31	1890
1891	30.58	.....	32.07	.....	.....	.....	.....	.....	.....	30.40	1891
1892	44.33	.....	34.65	.....	32.65	.....	.....	.....	.....	33.34	1892
1893	.....	.....	32.72	.....	.....	47.66	.....	32.75	41.45	29.04	1893
1894	.....	.....	.....	.....	25.86	32.36	.....	.....	35.14	23.82	1894
1895	26.76	.....	.....	.....	.....	31.73	.....	.....	25.88	.....	1895
1896	32.08	.....	.....	.....	27.19	35.87	.....	33.28	34.05	30.49	1896
1897	29.84	36.11	.....	.....	30.91	38.04	31.53	.....	44.34	.....	1897
1898	26.74	36.30	.....	.....	29.44	.....	36.17	31.70	40.41	.....	1898
1899	24.91	33.32	.....	.....	28.94	40.22	34.53	23.86	32.09	.....	1899
1900	32.97	29.22	.....	.....	32.68	48.10	33.44	.....	45.74	.....	1900
1901	30.02	25.58	.....	31.15	30.84	37.11	27.90	20.43	36.66	.....	1901
1902	44.45	43.64	.....	31.65	39.63	46.87	34.90	31.03	35.70	.....	1902
1903	37.86	26.22	.....	33.43	36.87	.....	33.89	25.23	.....	.....	1903
1904	27.09	23.25	.....	29.69	27.67	.....	33.13	21.94	.....	.....	1904

ANNUAL PRECIPITATION—Continued.

Years.	134 Buffalo, N. Y.	23 Calumet.	2 Charles City, Iowa.	60 Charlevoix.	81 Cheboygan.	29 Chicago, Ill.	123 Cleveland, O.	94 Clinton.	15 Clinton, Ia.	70 Coldwater.	Years.
1880	39.26	.....	28.08	.....	.....	37.32	37.38	.....	36.90	.....	1880
1881	35.95	.....	43.97	.....	.....	44.18	34.96	.....	41.16	.....	1881
1882	33.82	.....	28.83	.....	.....	41.34	39.98	.....	42.05	.....	1882
1883	38.07	.....	27.16	.....	.....	45.86	41.13	.....	38.68	.....	1883
1884	37.07	.....	.....	.....	.....	34.61	33.26	.....	43.04	.....	1884
1885	52.36	.....	.....	.....	.....	44.37	39.93	.....	38.21	.....	1885
1886	44.85	.....	.....	.....	.....	26.77	27.34	.....	29.74	.....	1886
1887	31.55	.....	.....	.....	.....	29.13	35.36	.....	33.01	.....	1887
1888	33.87	.....	.....	.....	.....	30.86	32.57	.....	35.76	.....	1888
1889	40.07	31.19	.....	.....	.....	34.95	32.57	.....	30.83	.....	1889
1890	46.55	27.37	.....	29.88	.....	32.69	47.82	31.89	32.22	.....	1890
1891	30.74	24.74	28.12	30.69	32.10	26.54	34.18	.....	33.38	.....	1891
1892	45.87	27.99	29.15	.....	.....	36.56	36.51	38.14	40.64	.....	1892
1893	38.64	25.98	28.27	27.75	24.97	27.47	33.88	34.46	30.39	.....	1893
1894	38.92	32.42	26.54	27.81	32.43	27.46	27.73	29.03	27.44	.....	1894
1895	32.02	36.82	25.01	26.96	27.66	32.38	26.84	23.51	30.38	.....	1895
1896	37.29	34.72	36.75	30.15	36.77	33.14	36.68	36.98	33.37	.....	1896
1897	37.72	28.64	27.32	30.93	28.84	25.85	24.54	33.74	23.77	.....	1897
1898	33.50	34.96	25.78	37.66	32.56	33.77	32.54	35.27	46.15	42.89	1898
1899	29.39	39.28	30.02	31.38	29.67	26.49	24.53	27.34	30.31	36.46	1899
1900	35.93	40.62	33.80	38.57	41.35	28.65	25.83	29.68	36.88	35.72	1900
1901	35.49	31.31	25.02	36.49	30.34	24.52	38.71	27.90	22.07	37.30	1901
1902	32.91	34.99	45.81	26.91	24.03	37.57	39.89	36.78	44.80	35.58	1902
1903	37.95	38.51	32.63	19.42	22.74	28.09	35.41	32.19	36.33	35.75	1903
1904	35.83	31.76	29.08	.....	.....	26.14	34.56	28.93	30.10	33.78	1904

Years.	4 Cresco, Ia.	13 Davenport, Ia.	115 Detroit.	12 Dubuque, Ia.	3 Duluth, Minn.	112 Eloise.	128 Erie, Pa.	32 Escanaba.	Evansville, Ind.	65 Farmland, Ind.	Years.
1880	38.06	42.73	47.68	40.32	38.11	.....	40.94	30.17	.....	.....	1880
1881	43.86	37.28	45.44	55.15	37.56	.....	37.62	48.49	.....	.....	1881
1882	32.58	36.60	30.32	32.84	38.02	.....	46.37	40.07	.....	.....	1882
1883	34.79	34.59	32.57	39.57	23.20	.....	44.81	30.02	.....	.....	1883
1884	34.69	38.11	28.17	42.86	35.85	.....	45.47	43.15	.....	.....	1884
1885	25.93	34.35	28.24	40.45	19.96	.....	52.13	31.42	.....	33.55	1885
1886	.....	23.15	26.71	27.51	33.37	.....	37.49	32.36	.....	41.80	1886
1887	26.60	31.23	28.97	34.40	28.56	.....	45.14	23.01	.....	.....	1887
1888	35.26	40.49	29.02	33.31	27.31	.....	31.94	25.89	.....	41.65	1888
1889	23.33	37.61	21.06	24.25	32.04	.....	37.66	26.77	.....	29.84	1889
1890	35.18	26.10	34.99	43.16	24.09	.....	47.05	30.02	.....	.....	1890
1891	28.19	31.45	28.83	27.55	29.47	.....	28.24	24.83	.....	41.06	1891
1892	36.33	44.15	37.11	48.77	28.52	.....	41.67	32.76	.....	42.85	1892
1893	30.58	27.33	34.18	30.77	23.34	.....	39.99	26.26	.....	42.73	1893
1894	23.76	18.52	25.74	19.35	31.70	.....	35.16	.....	.....	27.77	1894
1895	24.38	27.14	25.04	19.74	22.30	.....	35.55	.....	.....	30.38	1895
1896	34.07	28.68	36.20	42.29	27.19	.....	37.02	.....	.....	48.54	1896
1897	25.04	23.91	30.34	28.16	30.94	.....	34.34	28.55	52.70	37.12	1897
1898	23.91	38.95	34.34	35.48	19.70	33.64	34.07	30.11	44.78	.....	1898
1899	28.92	31.64	26.41	28.28	30.62	23.61	28.36	25.26	42.55	30.68	1899
1900	32.24	30.17	31.45	33.43	23.14	28.96	32.62	26.86	44.22	35.63	1900
1901	23.55	17.33	28.78	20.39	26.68	25.80	31.67	29.97	29.00	31.76	1991
1902	.....	40.31	35.53	38.34	26.14	.....	29.79	22.21	29.78	37.69	1902
1903	.....	35.73	35.88	31.79	28.01	31.49	35.58	32.58	35.45	36.27	1903
1904	.....	26.21	33.22	23.03	24.45	.....	41.28	32.40	42.94	43.77	1904

ANNUAL PRECIPITATION—Continued.

Years.	104 Findlay, O.	88 Fitchburg.	99 Flint.	9 Ft. Madison, Ia.	131 Franklin, Pa.	44 Grand Haven.	51 Grand Rapids.	1 Grantsburg, Wis.	107 Grape.	Years.
1880	.....	.....	.....	30.62	33.97	44.65	45.38	.....	.....	1880
1881	.....	.....	.....	38.34	39.07	47.89	43.18	.....	.....	1881
1882	.....	.....	.....	43.48	45.83	42.16	41.73	.....	.....	1882
1883	.....	.....	.....	43.19	41.28	44.84	48.63	.....	.....	1883
1884	.....	.....	.....	42.00	42.00	46.62	46.75	.....	.....	1884
1885	.....	.....	.....	28.45	44.56	35.81	38.04	.....	.....	1885
1886	.....	.....	.....	27.37	38.83	35.31	35.03	.....	.....	1886
1887	.....	.....	.....	28.14	40.82	32.75	38.83	.....	.....	1887
1888	.....	.....	.....	33.90	49.22	25.96	32.66	.....	25.14	1888
1889	.....	24.51	21.93	33.82	43.78	24.02	30.31	.....	24.12	1889
1890	42.75	42.21	.....	34.11	.....	32.26	34.40	38.90	30.34	1890
1891	37.92	32.63	25.03	30.12	.....	26.26	.....	.....	25.77	1891
1892	42.74	.....	25.67	39.23	.....	31.77	.....	.....	36.88	1892
1893	37.28	42.46	33.44	32.53	.....	34.97	.....	22.99	26.88	1893
1894	29.28	33.29	21.64	22.54	.....	32.61	26.18	27.93	26.41	1894
1895	28.46	32.45	21.34	32.31	.....	25.62	31.11	.....	20.64	1895
1896	38.64	38.43	25.14	37.66	.....	30.18	29.50	36.48	31.15	1896
1897	34.37	37.32	26.09	34.97	39.58	32.32	.....	34.42	30.98	1897
1898	41.52	35.08	27.48	51.00	39.07	36.02	34.61	29.14	32.43	1898
1899	30.80	26.00	29.32	42.06	.....	27.98	29.55	31.50	26.56	1899
1900	35.61	39.76	34.86	35.72	31.70	32.33	35.30	35.74	31.50	1900
1901	27.98	37.05	28.28	24.36	42.25	26.45	36.07	26.62	27.70	1901
1902	39.27	46.31	38.90	48.88	39.14	34.81	39.86	27.24	37.81	1902
1903	36.88	42.82	36.83	33.81	.....	.....	35.60	47.53	33.90	1903
1904	39.78	34.27	25.31	36.32	42.77	.....	27.93	34.77	30.98	1904

Years.	73 Grayling.	25 Green Bay, Wis.	80 Hanover.	117 Harbor Beach.	108 Harrisville.	37 Hart.	61 Hastings.	109 Hayes.	6 Hayward, Wis.	102 Highland.	Years.
1880	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1880
1881	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1881
1882	.....	.....	.....	.....	39.29	.....	39.16	.....	.....	.....	1882
1883	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1883
1884	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1884
1885	.....	.....	.....	.....	34.84	.....	.....	.....	.....	.....	1885
1886	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1886
1887	.....	32.56	.....	.....	.....	.....	.....	.....	.....	.....	1887
1888	.....	35.47	25.30	23.12	.....	33.73	31.11	.....	.....	.....	1888
1889	.....	32.56	25.68	22.62	.....	28.78	23.30	.....	.....	22.10	1889
1890	32.51	38.34	36.88	34.93	32.28	37.23	.....	.....	.....	32.71	1890
1891	28.74	26.03	33.06	28.70	39.31	32.25	.....	.....	24.45	32.46	1891
1892	.....	33.02	38.69	34.34	39.13	38.55	.....	.....	.....	32.10	1892
1893	.....	32.99	38.33	33.78	39.58	33.35	40.54	.....	.....	.....	1893
1894	20.28	35.89	31.37	25.30	34.96	.....	.....	.....	19.65	.....	1894
1895	23.61	21.04	27.60	24.83	28.72	26.70	.....	22.74	29.84	.....	1895
1896	24.45	33.09	40.29	24.09	32.62	.....	.....	.....	31.88	.....	1896
1897	28.84	34.13	37.29	28.62	37.95	34.30	32.67	30.68	.....	.....	1897
1898	33.24	29.08	39.97	25.70	35.84	30.65	34.59	25.18	29.18	.....	1898
1899	27,35	25.76	29.00	24.03	32.26	25.29	28.41	22.49	.....	.....	1899
1900	35.89	32.76	31.46	25.34	31.11	28.18	36.41	33.89	42.00	.....	1900
1901	28.40	26.46	32.01	17.46	31.71	28.24	31.34	20.18	28.17	29.86	1901
1902	32.17	27.61	33.61	34.69	34.59	31.98	38.35	37.79	28.55	38.99	1902
1903	.....	28.89	.....	28.88	36.05	.....	34,32	35.11	36.74	36.25	1903
1904	32.01	30.63	.....	18.65	31.71	.....	.....	.....	32.23	32.71	1904

ANNUAL PRECIPITATION—Continued.

Years.	77	96	122	54	26	5	63	85	119	57	Years.
	Hillsdale.	Howell.	Hudson, O.	Huntington, Ind.	Humboldt.	Independence, Ia.	Ivan.	Jackson.	Jeddo.	Kalamazoo.	
1880	.....	.....	.....	.....	.....	41.77	.....	.....	.....	41.17	1880
1881	.....	.....	.....	.....	.....	34.22	.....	.....	.....	40.27	1881
1882	.....	.....	.....	.....	.....	34.56	.....	.....	.....	33.70	1882
1883	.....	.....	.....	.....	.....	33.80	.....	.....	.....	36.33	1883
1884	.....	.....	.....	.....	.....	43.62	.....	.....	.....	39.99	1884
1885	.....	.....	38.02	.....	.....	34.44	.....	.....	.....	40.51	1885
1886	.....	.....	30.93	.....	.....	27.34	.....	.....	.....	32.21	1886
1887	.....	.....	35.03	.....	.....	35.06	.....	.....	.....	34.48	1887
1888	.....	.....	34.62	37.08	.....	32.51	.....	.....	.....	28.03	1888
1889	.....	.....	.....	29.00	.....	24.52	.....	.....	.....	28.50	1889
1890	.....	.....	.....	37.82	.....	35.11	31.43	.....	34.85	35.96	1890
1891	.....	32.37	37.56	32.30	.....	28.13	35.14	.....	26.42	34.41	1891
1892	.....	30.42	.....	44.65	.....	33.74	36.30	.....	30.26	33.33	1892
1893	.....	34.65	.....	.....	.....	21.45	.....	.....	30.49	34.60	1893
1894	.....	24.61	.....	27.61	.....	20.98	31.10	.....	24.55	26.07	1894
1895	.....	24.85	.....	24.83	.....	20.67	26.37	.....	27.73	31.57	1895
1896	.....	36.77	40.29	50.73	.....	34.26	30.49	.....	27.38	.....	1896
1897	.....	.....	40.27	38.89	20.81	25.74	.....	.....	32.32	36.49	1897
1898	39.78	.....	45.84	43.04	21.42	28.31	38.49	31.64	31.59	28.93	1898
1899	35.23	.....	38.75	34.58	36.56	23.41	.....	26.71	31.67	36.48	1899
1900	36.48	.....	31.10	42.18	30.19	37.37	33.96	29.61	33.63	35.29	1900
1901	32.84	19.36	36.30	35.24	26.03	19.61	30.19	28.33	23.30	21.25	1901
1902	34.69	.....	44.50	43.63	20.33	46.14	34.05	37.10	39.33	38.17	1902
1903	43.16	.....	.....	39.40	.....	.....	.....	36.42	32.13	.....	1903
1904	37.64	.....	39.81	42.10	.....	21.62	27.59	28.94	25.91	.....	1904

Years.	7	20	8	33	84	31	87	40	75	89	Years.
	Keokuk, Ia.	Keopenick, Wis.	La Crosse, Wis.	Lafayette, Ind.	Lansing.	Lathrop.	Lewiston.	Logansport, Ind.	Mackinaw.	Madison.	
1880	34.54	.....	34.34	.....	49.38	.....	.....	41.55	.....	.....	1880
1881	39.01	.....	44.74	.....	35.28	.....	.....	43.58	.....	.....	1881
1882	41.54	.....	27.93	46.01	32.17	.....	.....	46.52	.....	.....	1882
1883	38.63	.....	33.69	42.71	46.27	.....	.....	48.20	.....	.....	1883
1884	32.88	.....	35.31	37.87	36.21	.....	.....	38.29	.....	.....	1884
1885	35.11	.....	30.70	38.83	40.31	.....	.....	43.62	.....	.....	1885
1886	29.66	.....	22.49	34.53	29.52	.....	.....	.....	.....	.....	1886
1887	26.33	.....	17.37	26.82	30.08	.....	.....	38.07	.....	.....	1887
1888	35.79	.....	34.85	33.26	25.76	.....	.....	.....	.....	26.77	1888
1889	34.75	.....	24.37	34.10	22.74	28.38	.....	.....	.....	26.23	1889
1890	26.93	.....	34.77	42.52	34.54	34.14	32.45	42.09	.....	34.36	1890
1891	33.24	23.95	26.98	36.65	29.05	25.33	.....	29.05	.....	35.59	1891
1892	37.45	35.20	36.19	43.48	32.06	.....	33.19	36.84	.....	42 73	1892
1893	27.94	29.65	24.64	37.07	39.52	.....	32.62	.....	.....	33.19	1893
1894	25.20	23.80	22.94	35.22	24.69	.....	25.19	26.77	.....	29.20	1894
1895	29.82	24.64	22.97	27.07	27.40	31.11	23.54	25.69	.....	23.91	1895
1896	36.77	32.20	29.15	38.65	32.67	33.00	33.74	32.91	.....	34.92	1896
1897	33.14	25.50	21.32	33.34	35.32	26.95	.....	28.33	27.49	26.53	1897
1898	51.48	30.40	23.49	44.38	31.56	32.63	.....	32.51	32.86	34.01	1898
1899	40.97	31.30	35.35	30.84	25.00	.....	.....	24.84	33.41	28.62	1899
1900	33.61	46.55	41.85	42.74	33.29	33.47	.....	30.96	46.46	31.94	1900
1901	22.54	33.00	34.93	32.01	35.17	45.90	.....	29.52	35.91	.....	1901
1902	38.86	27.70	30.26	45.94	37.04	.....	.....	39.96	31.43	.....	1902
1903	33.28	42.86	30.40	33.67	36.68	.....	.....	38.38	40.96	.....	1903
1904	38.93	43.00	25.41	39.07	27.11	.....	.....	32.43	.....	.....	1904

ANNUAL PRECIPITATION—Continued.

Years.	18 Madison, Wis.	66 Manelona,	36 Manistee,	41 Manistique.	28 Manitowoc, Wis.	120 Mansfield, O.	22 Marengo, Ill.	30 Marquette.	110 Mayville.	16 Meadow Valley, Wis.	Years.
1880	46.72	.....	.....	.....	.....	.....	33.29	33.44	.....	.....	1880
1881	52.93	.....	.....	.....	37.55	.....	47.42	42.91	.....	.....	1881
1882	42.89	.....	.....	.....	40.13	.....	35.36	37.08	.....	.....	1882
1883	.....	.....	.....	.....	38.12	.....	35.91	30.50	.....	.....	1883
1884	49.24	.....	.....	.....	40.51	.....	34.95	41.44	.....	.....	1884
1885	40.58	.....	.....	.....	31.80	.....	35.78	28.60	.....	.....	1885
1886	28.78	.....	.....	.....	33.05	.....	31.24	29.27	.....	.....	1886
1887	38.89	.....	.....	.....	26.47	.....	33.24	25.62	.....	.....	1887
1888	22.86	.....	.....	.....	30.73	40.95	26.41	35.46	.....	.....	1888
1889	20.17	.....	29.67	.....	28.52	38.16	.....	30.31	.....	.....	1889
1890	36.97	.....	36.25	.....	32.86	53.02	.....	34.47	31.69	.....	1890
1891	24.33	.....	28.79	.....	24.58	42.16	.....	33.78	35.63	24.86	1891
1892	37.07	.....	35.15	.....	32.76	42.77	.....	27.28	31.38	32.76	1892
1893	31.43	.....	.....	.....	30.95	45.35	.....	35.86	35.36	.....	1893
1894	23.79	.....	.....	.....	25.48	33.01	.....	35.58	.....	20.89	1894
1895	13.12	.....	.....	.....	19.76	.....	.....	33.04	29.08	19.56	1895
1896	30.02	.....	.....	35.62	31.23	.....	.....	29.59	29.04	31.88	1896
1897	22.58	42.34	29.85	30.40	26.58	38.02	.....	30.03	.....	24.44	1897
1898	31.91	37.23	32.14	.....	25.70	54.29	.....	27.48	.....	29.74	1898
1899	27.04	29.96	.....	.....	21.30	44.13	.....	36.43	.....	31.44	1899
1900	29.60	39.81	.....	32.69	29.34	47.60	.....	32.32	.....	35.66	1900
1901	20.24	40.46	32.17	32.18	25.91	45.11	.....	37.19	.....	32.08	1901
1902	.....	33.69	33.22	32.09	32.90	36.97	.....	26.77	.....	33.12	1902
1903	34.84	17.37	.....	35.92	32.16	37.88	.....	39.84	.....	34.80	1903
1904	30.69	.....	.....	.....	30.29	45.43	.....	33.24	.....	27.83	1904

Year	14 Medford, Wis.	27 Milwaukee, Wis.	10 Monticello, Ia.	49 Mottville.	11 Muscatine, Ia.	38 Muskegon.	127 Newcastle, Pa.	105 N. Lewisburg, O.	69 North Marshall.	55 Old Mission.	Year.
1880	.....	29.96	46.05	.....	35.78	.....	33.60	46.05	.....	.....	1880
1881	.....	39.07	50.03	.....	45.66	.....	32.20	43.65	.....	.....	1881
1882	.....	28.43	35.56	.....	46.67	.....	.....	45.75	.....	.....	1882
1883	.....	29.47	35.94	.....	41.12	.....	.....	48.80	.....	.....	1883
1884	.....	30.57	37.77	.....	45.49	.....	.....	34.30	.....	.....	1884
1885	.....	32.58	40.28	.....	39.14	.....	.....	38.95	.....	.....	1885
1886	.....	31.46	29.36	.....	31.22	.....	.....	44.05	.....	.....	1886
1887	.....	30.46	33.95	.....	28.30	.....	.....	35.05	.....	.....	1887
1888	.....	23.49	34.69	27.47	38.89	.....	.....	47.10	.....	.....	1888
1889	.....	31.76	26.28	26.30	33.47	.....	.....	31.05	24.89	.....	1889
1890	37.84	30.09	44.05	.....	31.87	.....	52.53	45.25	36.28	.....	1890
1891	30.45	29.76	27.38	29.51	35.26	.....	35.42	44.25	.....	.....	1891
1892	37.33	35.03	38.09	33.85	42.30	.....	34.45	40.45	.....	.....	1892
1893	30.07	32.87	27.98	34.01	31.20	.....	42.80	49.50	32.02	.....	1893
1894	27.02	27.79	25.78	29.39	29.12	.....	.....	39.85	22.73	.....	1894
1895	28.23	24.88	18.57	.....	.....	.....	.....	28.95	24.49	23.23	1895
1896	.....	28.98	31.59	32.62	.....	.....	.....	48.30	39.23	.....	1896
1897	27.38	31.05	.....	31.33	.....	26.46	.....	.....	33.75	33.69	1897
1898	28.23	32.43	.....	41.82	.....	26.13	.....	52.23	.....	.....	1898
1899	31.98	22.82	27.82	32.28	.....	26.22	.....	34.00	.....	28.00	1899
1900	44.93	30.10	31.75	.....	.....	27.74	.....	32.47	.....	.....	1900
1901	29.05	18.69	20.66	.....	.....	29.65	.....	29.57	.....	30.49	1901
1902	42.05	28.63	.....	.....	.....	33.46	.....	36.65	39.25	.....	1902
1903	46.15	33.41	.....	.....	.....	32.41	.....	28.70	.....	34.33	1903
1904	41.10	29.86	.....	.....	.....	38.19	.....	35.41	.....	26.04	1904

ANNUAL PRECIPITATION—Continued.

Year.	72 Olivet.	90 Owosso.	53 Parkville.	129 Parry Sound, Ont.	17 Peoria, Ill.	68 Petoskey.	130 Pittsburg, Pa.	19 Port Arthur, Ont.	121 Port Huron.	83 Ovid.	Year.
1880	.....	.....	46.75	42.85	39.89	.....	31.97	29.58	38.68	.....	1880
1881	.....	.....	53.88	33.26	41.05	.....	37.30	26.63	35.27	.....	1881
1882	.....	.....	57.78	34.84	40.04	.....	38.63	21.35	41.04	.....	1882
1883	.....	.....	56.81	42.51	36.53	.....	43.17	22.75	36.98	.....	1883
1884	.....	.....	43.43	34.06	41.80	.....	34.82	25.78	29.19	.....	1884
1885	.....	.....	55.70	40.40	32.40	.....	34.12	18.84	33.81	.....	1885
1886	.....	.....	43.03	39.14	28.60	.....	39.21	23.28	29.84	.....	1886
1887	.....	.....	40.90	34.05	27.30	.....	41.95	25.48	24.82	.....	1887
1888	.....	.....	31.67	32.62	38.22	.....	39.89	26.36	24.33	24.02	1888
1889	26.79	.....	40.22	33.43	35.05	.....	41.37	24.50	22.22	22.90	1889
1890	32.79	.....	46.65	39.44	25.26	.....	50.61	20.17	32.95	31.63	1890
1891	28.02	.....	34.22	38.06	32.89	28.57	38.28	20.52	33.81	28.69	1891
1892	.....	.....	37.61	43.89	35.66	38.03	32.66	19.12	33.95	31.55	1892
1893	.....	.....	42.65	48.03	33.70	.....	37.84	23.15	34.80	38.27	1893
1894	.....	.....	30.76	39.39	28.30	32.00	28.17	22.52	26.92	24.81	1894
1895	.....	.....	30.68	38.14	33.87	.....	27.50	22.47	26.11	25.20	1895
1896	47.94	32.52	39.23	33.30	36.37	.....	44.35	21.50	28.43	31.78	1896
1897	37.56	31.37	34.97	46.28	33.44	34.51	35.08	24.51	32.10	30.70	1897
1898	37.09	32.17	39.63	39.99	43.36	37.50	35.76	28.14	33.14	29.01	1898
1899	29.60	.....	.....	43.99	33.26	.....	33.85	26.53	25.85	28.67	1899
1900	43.74	33.28	.....	42.28	32.70	.....	25.73	27.09	28.73	30.15	1900
1901	34.84	27.50	.....	50.30	26.59	29.64	40.76	22.51	20.36	33.42	1901
1902	43.74	39.13	.....	45.23	51.62	17.49	32.22	21.82	35.77	34.61	1902
1903	40.03	.....	.....	38.22	39.95	29.48	38.81	22.11	32.91	33.20	1903
1904	34.45	.....	.....	39.27	35.49	45.51	36.68	22.27	24.97	31.48	1904

Year.	125 Port Stanley, Ont.	56 Reed City.	93 Saginaw, W. S.	74 St. Ignace.	78 St. Johns.	35 St. Joseph.	118 Sandusky, O.	124 Saugeen, Ont.	82 Sault Ste. Marie.	86 Somerset.	Year.
1880	38.80	40.77	.....	.....	.....	.....	39.44	37.87	.....	.....	1880
1881	32.52	47.91	.....	.....	.....	.....	46.31	32.97	.....	.....	1881
1882	32.64	34.36	.....	.....	.....	.....	42.53	28.16	.....	.....	1882
1883	.....	41.42	.....	.....	.....	.....	.....	37.97	.....	.....	1883
1884	26.32	40.85	.....	.....	.....	.....	33.64	34.13	.....	.....	1884
1885	35.43	38.40	.....	.....	.....	.....	34.23	37.50	.....	.....	1885
1886	37.88	.....	.....	.....	.....	.....	31.00	36.47	.....	.....	1886
1887	29.63	.....	.....	.....	.....	.....	29.85	33.78	.....	.....	1887
1888	30.80	.....	.....	.....	27.50	31.57	26.45	31.54	.....	.....	1888
1889	35.85	.....	.....	.....	24.98	.....	24.98	35.11	35.39	.....	1889
1890	43.39	.....	.....	37.67	31.04	39.62	38.60	35.66	40.06	.....	1890
1891	35.27	.....	.....	29.09	.....	.....	30.69	37.90	29.57	.....	1891
1892	38.31	.....	.....	30.11	.....	49.20	43.28	41.51	30.09	.....	1892
1893	40.94	.....	.....	33.51	.....	44.41	29.00	34.73	39.64	.....	1893
1894	30.54	.....	.....	32.17	.....	.....	28.09	28.16	38.53	.....	1894
1895	30.94	.....	.....	26.70	26.11	.....	26.82	32.95	30.55	.....	1895
1896	36.68	.....	.....	33.37	.....	.....	31.76	28.38	34.62	.....	1896
1897	34.47	30.34	35.49	28.35	29.52	24.68	28.45	40.41	36.16	33.39	1897
1898	39.50	.....	38.40	29.79	25.73	34.98	43.17	30.90	27.91	33,98	1898
1899	30.60	29.48	29.22	22.05	28.66	26.36	30.78	32.05	30.68	31.77	1899
1900	36.09	34.36	35.28	35.35	.....	.....	31.80	31.55	30.93	.....	1900
1901	32.50	26.20	28.27	32.43	.....	27.05	25.50	35.96	27.38	22.82	1901
1902	42.59	35.77	40.99	27.23	.....	45.12	36.83	34.72	26.00	23.57	1902
1903	41.15	.....	37.31	.....	.....	32.47	33.57	35.92	29.04	.....	1903
1904	35.13	.....	28.81	.....	.....	.....	31.87	29.02	27.50	.....	1904

ANNUAL PRECIPITATION—Continued.

Year.	45 So. Haven.	126 Stratford, Ont.	113 Thornville.	103 Toledo, O.	132 Toronto, Ont.	50 Traverse City.	46 Vandalia.	101 Vassar.	133 Warren, Pa.	59 Wasepi.	Year.
1880	.....	45.57	29.50	35.72	35.32	.....	.....	.....	.....	.....	1880
1881	.....	31.31	29.50	45.91	27.11	.....	.....	.....	.....	.....	1881
1882	.....	36.98	33.57	33.03	24.85	45.30	.....	.....	.....	.....	1882
1883	.....	45.50	40.83	34.24	34.16	43 42	.....	.....	.....	.....	1883
1884	.....	42.94	.....	28.43	28.56	42.59	.....	.....	.....	.....	1884
1885	.....	41.20	30.67	33.19	33.91	38.84	.....	.....	50.41	.....	1885
1886	.....	39.15	30.76	32.70	35.09	42.77	.....	.....	34.11	.....	1886
1887	.....	42.02	31.41	32.01	25.83	33.06	.....	.....	32.54	.....	1887
1888	.....	.....	25.56	25.86	26.26	.....	.....	.....	.....	.....	1888
1889	.....	.....	24.10	21.84	31.04	35.91	28.79	.....	39.76	.....	1889
1890	.....	.....	39.76	33.64	37.46	.....	40.11	.....	58.22	.....	1890
1891	.....	.....	35.99	27.12	31.33	.....	33.41	.....	51.37	.....	1891
1892	.....	.....	31.53	36.70	29.52	.....	38.38	.....	47.56	.....	1892
1893	.....	.....	32.60	23.81	38.63	.....	39.15	.....	48.71	.....	1893
1894	.....	.....	23.25	21.34	29.64	.....	31.71	.....	.....	.....	1894
1895	.....	.....	27.78	25.31	28.05	.....	30.84	.....	33.54	.....	1895
1896	.....	.....	31.78	33.10	29.11	.....	35.83	.....	41.23	.....	1896
1897	.....	.....	29.20	30.55	32.44	31.74	36.90	.....	37.51	30.33	1897
1898	.....	.....	29.23	28.10	30.95	37.43	40.91	28.03	47.32	37.64	1898
1899	26.50	.....	29.09	27.06	28.94	25.53	38.42	.....	45.42	34.76	1899
1900	40.00	.....	30.49	29.58	29.60	33.95	.....	31.90	41.34	35.95	1900
1901	25.60	.....	28.65	26.29	32.19	31.85	.....	32.07	46.51	33.87	1901
1902	36.46	.....	41.81	33.31	31.07	.....	.....	31.45	40.67	39.49	1902
1903	34.70	.....	39.93	35.08	30.63	31.25	.....	27.93	40.85	40.65	1903
1904	30.99	.....	28.39	27.94	35.99	32.31	.....	.....	44.51	40.61	1904

Year.	91 Wauseon, O.	34 Wetmore.	67 White River, Ont.	21 Winnebago, Ill.	100 Ypsilanti.	Year.
1880	41.00	.....	.....	.....	.....	1880
1881	48 04	.....	.....	.....	.....	1881
1882	33.56	.....	.....	.....	.....	1882
1883	41.59	.....	.....	.....	.....	1883
1884	32.91	.....	.....	.....	.....	1884
1885	36.00	.....	.....	.....	.....	1885
1886	30.38	.....	.....	.....	.....	1886
1887	34.14	.....	.....	.....	.....	1887
1888	28.67	.....	.....	.....	28.38	1888
1889	35.33	.....	33.18	28.05	29.20	1889
1890	39.29	.....	25.24	30.11	36.44	1890
1891	37.11	.....	17.07	30.04	32.55	1891
1892	52.55	.....	19.00	45.07	41.75	1892
1893	42.74	.....	28.12	29.36	38.30	1893
1894	32.04	.....	23.88	26.39	29.85	1894
1895	29.06	.....	26.08	25.41	25.87	1895
1896	46.61	.....	26.42	32.53	35.77	1896
1897	38.85	31.35	17.58	29.27	34.60	1897
1898	48.77	30.61	27.85	39.19	36.10	1898
1899	36.81	33.44	25.79	30.89	29.26	1899
1900	39.38	33.46	27.78	39.74	35.98	1900
1901	35.32	.....	27.28	24.43	30.83	1901
1902	44.85	.....	28.49	41.91	41.77	1902
1903	38.93	22.97	29.46	42.55	36.60	1903
1904	36.36	28.82	27.42	34.49	33.34	1904

RAISED BEACHES OF EASTERN WISCONSIN.

JAMES W. GOLDTHWAIT.

(Abstract.)*

A detailed study of the abandoned shore lines of eastern Wisconsin, carried on in the summer of 1905 for the Wisconsin Geological and Natural History Survey, makes it possible not only to identify the beaches and terraces of successive stages of Lakes Chicago, Algonquin, and Nipissing, but to reconstruct the extinct water planes with considerable accuracy.

Conspicuous step-like terraces on Washington island and the Door county peninsula mark three important stages of Lake Algonquin, and a twenty-foot water plane, believed to be the plane of the "Nipissing" shore. These shore lines were traced southward along the western side of Lake Michigan (and less easily along the east and west sides of Green Bay); and the profile of the whole series was measured in more than fifty localities, by means of the spirit or "wye" level. Assembling all of this data, it is found that the water planes of Lake Algonquin stand in warped attitudes, the direction of steepest inclination being about N. 15° E. Each plane rises more steeply as it extends northward, and the higher planes slant more steeply than the lower.

From ninety-five feet above Lake Michigan at Washington island, the highest Algonquin beach declines southward at an ever decreasing rate, until it seems to become horizontal at twenty-six feet near Two Rivers. South of that point it has been lost by more recent erosion, but seems to be correlated with the "Toleston" beach at Evanston, Illinois, which is twenty-four feet above the lake on the campus at Northwestern University.

The Nipissing shore line, everywhere a prominent feature, declines almost imperceptibly from an altitude of twenty to twenty-two feet at Washington island to fourteen feet at Centerville (near Manitowoc), becoming horizontal at that height, and thus encircling the southern end of Lake Michigan. In southeastern Wisconsin and northeastern Illinois (north of Waukegan) it has commonly cut back beyond the earlier Algonquin shore line. Stream terraces, however, and a few scraps of Algonquin shore terraces seem to fix the Algonquin plane at the twenty-four-foot level.

The Toleston-Algonquin shore line, horizontal at twenty-four feet, and the Nipissing shore line, horizontal at fourteen feet, in the southern part of the Michigan basin, correspond to the horizontal twenty-five-foot Algonquin beaches and the fourteen (?) foot Nipissing shore line in the southern part of the Huron basin. South of the vicinity of Manitowoc, there seems to have been no tilting since the beginning of Lake Algonquin.

This correlation of shore lines involves the use of the Chicago outlet as one of the outlets for Lake Algonquin at its highest stage.

Evanston, Ills.

*The full paper will be published by the Wisconsin Geological Survey.

SYMPOSIUM ON WATER SUPPLIES IN MICHIGAN.

GEOLOGICAL CONDITIONS OF MUNICIPAL AND INSTITUTIONAL WATER SUPPLIES IN MICHIGAN.*

FRANK LEVERETT.

SOURCES OF SUPPLY.

The details concerning the sources and geological conditions of the public water supplies of Michigan are found in the table presented below. From this table it appears that the Great Lakes and their connecting streams supply thirty-seven cities and villages with an aggregate population of about 500,000; the inland lakes seventeen towns with a population of 65,000; the inland streams forty towns with a population of about 200,000, while impounded water is used in seven towns with a population of 11,200. Springs are drawn upon wholly or in part by eighteen villages and three institutions with a population of about 30,000. Infiltration wells are drawn upon by five towns with a population of 39,000. Underground supplies are from the following sources: (a) Shallow drift wells, either excavated or driven, supplied from the surface part of the ground water, used in twenty-seven cities and villages, including Muskegon and South Haven which have pipes under the lake bed and are included also in the thirty-seven towns supplied from the Great Lakes, with a population of over 80,000; (b) wells carried deep into water bearing stratum but without passing through an impervious bed, in use by eighteen towns with a population of about 45,000; (c) wells from gravel or sand under clay in use by fifty-one towns and institutions with a population of 100,000; (d) shallow rock wells, less than 100 feet in depth, in use in four towns with a population of 5,765; (e) deep rock wells, 100 to 600 feet in depth, in use in twenty-five villages and five institutions with a population of about 100,000. Of this last class twenty towns with a population of 88,150 and the five institutions with 3,800 draw water from standstone, leaving only four supplied from limestone.

CHARACTERISTICS OF SURFACE WATER.

Hardness. The waters of the Great Lakes and their connecting streams (St. Marys, St. Clair and Detroit Rivers) are found to contain a smaller amount of mineral matter and to be softer than the average waters of the inland lakes and streams, there being only one-third to two-thirds as much calcium and magnesium carbonate in the waters of the Great Lakes as in the inland rivers. This results naturally from the fact that a large part of the supply to the Great Lakes is by direct rainfall, the area of the lakes being nearly half that of their watersheds,

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while inland lakes and streams are supplied very largely through the drainage from their watersheds both surface and underground.

Of the Great Lakes, Superior has much softer water than Michigan, Huron and Erie, there being less than half the amounts of calcium and magnesium carbonates in its waters. Available analyses show for Lake Superior waters about forty parts per million of carbonates of calcium and magnesium, for Lake Michigan waters eighty to ninety-two parts, while those of inland surface waters of the Southern Peninsula run from 100 up to 300 parts per million. (See Lane Water Supply Paper, U. S. Geological Survey No. 31, also Annual Report of State Geologist for 1903, pp. 112-161.) This variation is readily accounted for by the geological conditions, limestone or other rock formations which give hardness to percolating water being poorly represented within the Lake Superior watershed compared with their occurrence within the watersheds of the three other lakes. The glacial deposits also being composed largely of material of local derivation contain much less calcareous material within the Lake Superior watershed. Lake Superior is not only softer than the other Great Lakes, but its waters remain cooler through the summer months so that it is the most palatable of all the waters. The cities on its borders, therefore, have an unexcelled water supply so far as geological and geographical conditions are concerned. The waters of the other Great Lakes are also suitable for boiler use and are largely drawn upon to supply commercial and manufacturing needs.

The hardness of the inland lakes and streams like that of the underground waters is found to be generally above 140 parts per million, or the limit considered suitable for good boiler water, though there are a few notable exceptions where lakes have very small affluents.

Turbidity. The Michigan streams as a rule carry so little matter in suspension that so far as sediment is concerned they appear well adapted for domestic use and all other purposes where clear water is desired. The small amount of sediment carried by them is due to the fact that much of their supply comes through underground instead of surface runoff, the drift deposits being so porous that a large part of the rainfall is directly absorbed and then fed slowly to the streams by seepage. Since the slopes have been cleared and cultivated, and conditions made more favorable for surface runoff the streams are more frequently turbid than they were in the natural state of the country, but even now the condition of Michigan streams in this respect is better than any of the neighboring states. In some cases turbidity is caused by winds and the currents which they produce. The lake currents bring sand to the outlet of Lake Huron and this is carried through the St. Clair River to form the delta at the north edge of Lake St. Clair. Port Huron and other cities drawing supplies from St. Clair River thus have a somewhat turbid supply. At the head of Saginaw Bay the water is so shallow that storms disturb the sand and render it turbid for some miles from the shore but this condition is only occasional and is therefore of slight detriment to the Bay City supply. The waters of the lakes are very clear except in the shallows where waves and currents stir up the sand. The disturbing effect of waves on the shores has made it necessary at several points to extend intake pipes out into deep water.

The inland lakes are in some cases shallow and rendered turbid by storms, but a large number of them occupy deep basins with only a narrow fringe of shallow water so that it is an easy matter to extend the pipes into water that is always clear. To many lakes the tributary streams are of little consequence and there are very few in which a marked turbidity is caused by the inflow from streams. In marl lakes however, there is in some cases constant turbidity because of the action of waves on the marly shores.

Lake currents in reference to contamination. Lake currents become of vital interest in connection with several of the public water supplies of Michigan cities. One of the most striking instances is that of Marquette. The waterworks supply is taken from a harbor north of Light House Point from an intake pipe which extends only 850 feet into the lake and terminates in 26 feet of water. The sewage is all carried into a harbor south of Light House Point. The shortness of this intake pipe suggested the advisability of taking water from farther out, but fortunately the city took the precaution to test the water throughly before making the extension. A small test pipe was carried out to a distance of 3200 feet and samples have been taken from it monthly for the past year and, together with samples from the present intake pipe, were sent to the Hygienic Laboratory of the University for examination. The superintendent of the waterworks informed the writer last October that the analyses of water from the long pipe showed greater contamination than that of water from the short pipe. The long pipe appears, therefore, to be in the path of a current leading out from the sewer laden harbor while the short pipe is out of the path of that current. While therefore, in general, the greater extension of pipe tends to secure a better water, in this case it may secure a poorer water.

On Little Bay de Noc are two neighboring cities, Gladstone and Escanaba, one of which has felt no serious results from the use of the water from the bay while the other has for several years been ravaged by epidemics of typhoid fever. Gladstone, the favored city, stands nearer the head of the bay and opposite a very narrow part. Streams entering the head of the bay cause a preceptible current past this narrow part so that the sewage is seldom or never carried to the intake pipe. Escanaba is not so fortunately situated and the currents appear to mingle the sewage with the water taken for the city consumption at such frequent intervals as to greatly pollute the supply. Plans are now pending for the installation of a filtration plant to purify the water, but it is unfortunate that the city has turned its sewage and allowed the sewage from a hospital to be turned into its source of water supply, when it might at a slight additional expense have turned the sewage into a stream back of the city which would have carried it beyond the part of the bay from which the city supply is taken. However, contamination may occur in lake ports, such as Escanaba, from diseased persons on vessels standing in the harbor as was the case at Sault Ste Marie, so that a filtration plant should be installed in every lake port which draws its supply from a harbor. Inasmuch as the sanitary conditions of the water supplies will be treated by another it is unnecessary to go farther into the matter at this point.

CHARACTERISTICS OF UNDERGROUND WATERS.

Hardness. It is rare to find an underground water supply in which the amount of carbonates of calcium and magnesium fall below 140 parts per million, and in a large part of the State sulphates are also present to increase the hardness. The softest waters appear to be obtained from sand dunes and very shallow wells in sand deposits on the old beds of lakes which extended somewhat beyond the limits of the present Great Lakes. There are also occasional waters from sandstone formations, and from near the base of the drift (where a supply from underlying sandstone is suspected) in which the waters are soft enough to be fair for boiler use.

Salinity. The salt or brackish waters of Michigan are generally confined to rock formations lying at considerable depth, but there are parts of the Saginaw basin and also places near the borders of Lake St. Clair in which the waters in the glacial deposits are found to carry enough salt to render them objectionable for drinking. In such cases it is supposed that the salt water has risen into the glacial deposits from underlying rock formations, though it is barely possible that the drift deposits themselves carry enough saline matter in these localities to cause excessive salinity of the water. It is worthy of note, that throughout the southern portion if not throughout the entire State a small amount of salt is found in the waters from the drift where no contamination by human agencies has occurred. The amount of chlorine or sodium chloride found by an analyst is not therefore to be taken as a measure of contamination. References may be made to the report of Dr. Lane on Lower Michigan Mineral Waters (Water Supply Paper 31) for numerous analyses which will throw light upon the saltness of water in various localities and at different geological horizons.

Iron. In many of the underground waters iron is present in sufficient amount to color the boiler scale and also to induce the growth of iron-loving organisms such as crenothrix at points within the water pipes or system. The amount of iron necessary to induce the growth of these organisms is small compared with the total solids, less than five parts per million apparently being sufficient. Chemists have found that having the standpipe covered, and light excluded, will greatly retard organic growths in the water. It is a popular notion that the brown, slimy material found along the course of escaping water is mainly iron oxide; but in many cases it is an organic growth, the iron being present only as a stain. Many of the waters from deep wells in the drift, however, contain considerable iron and it is also present in waters from rock formations. Thus at Battle Creek the waters from the Marshall sandstone have been found by analyses made at the University to contain 2.5 to 4 parts per million of iron and the city has wisely delayed a a change to this supply until the effect of the iron has been determined.

Other objectionable constituents. Mention need scarcely be made of bitter water (caused by the presence of magnesium sulphate and magnesium chloride) for it is found in only a few localities and is generally avoided for public water supplies, not only because it is not palatable, but because it scales and corrodes badly by dissociation of the sulphate and production of sulphuric acid.

A much more common agent of corrosion is free carbonic acid gas

which is present in large amounts in many of the deep well waters, both from drift and rock, and is met with all over the State. This actively corroding agent probably does much of the damage that so commonly is referred to iron in the water.

Sulphuretted hydrogen especially when associated with calcium sulphate renders water objectionable, but there are only limited districts in which the amount is sufficient to be a source of much inconvenience.

There are limited districts in which oil and inflammable gas have accumulated in the water bearing beds that underlie compact clay, a notable instance of gas accumulation being the district between Milan and Ypsilanti, while oil is especially abundant in wells west of Howell. The oil and gas besides being objectionable in the water give rise to wild speculation as to their occurrence in paying quantities underneath the water bearing formation. The hopes thus aroused are seldom if ever likely to be realized. The gas of the Milan district appears to be largely from the underlying Devonian shale, while the oil near Howell appears to have been distilled from limestone which there immediately underlies the drift.

Turbidity. The underground waters are seldom turbid, for as a rule the supplies come from beds of sand and gravel too coarse to be held in suspension. There are, however, occasional flowing wells which constantly bring up sediment because of the fineness of material in which the water is obtained. For example, flowing well districts near Pickford and near Rudyard in Chippewa County penetrate large amounts of very fine sand termed "slush" by the drillers, in which some of the wells that terminate in the slush are troubled with turbid water, but the majority reach coarser material. There are also a few places where wells terminate in a marsh mud or in very clayey beds in which water is frequently if not continually turbid.

GEOLOGICAL CONDITIONS FROM SANITARY STANDPOINT.

The leading question in determining a public water supply is that of the healthfulness of the water to the consumer. A study of the sources of supply in use in Michigan cities and villages brings out numerous instances in which the choice of a public supply has been unwise. The individual cases cannot be taken up, but a few general observations will be presented.

It has already been pointed out that the surface waters contain much less mineral matter than the underground waters and on that account they are preferable for drinking and for boiler use, but the chances for contamination are greater than in underground waters. It would seem wise, therefore, wherever surface waters are to be turned into a public supply to have well equipped filtration plants connected with the waterworks system. By this means greater safety will be insured to the 600,000 people who are already using such water and the much larger number which will use it in the future.

The underground waters are in most cases practically free from danger of contamination. There are, however, certain situations in which the deposits from which water is drawn are liable to become contaminated. The coarse deposits of gravel and sand along water courses that lead through villages are thus exposed and yet are drawn upon in a

large number of towns. The water in its underground course naturally works towards the stream carrying with it the contamination which has been received from the bordering districts occupied by the villages. In spite of this fact water-works plants have in some cases been located on the river banks at about the worst place which could have been selected, the determining matter being the convenience of location rather than the safety. In such cases the water-works might generally have been located above the towns with a supply fully as great and with but little additional expense. With the heavy drafts made by pumping the contributing district is enlarged and the danger increased; thus water which at the time of the installation of the wells was found by analysis to be uncontaminated may not long remain safe for use.

It is generally true that flowing wells form a safe source of water supply, since their catchment areas are somewhat remote and the water must flow some distance underground to reach the wells. There are, however, instances in which flowing well districts located in valleys with rapid descent are supplied from the adjacent portions of a valley and its slopes. If such a catchment area is thickly inhabited there is more or less danger of contamination.

Instances have also come to notice of carelessness in the conducting of water from flowing wells to the reservoirs or receiving wells, ordinary drain tile being laid at a slight depth beneath the surface to conduct the water into the receiving well. Where the drain tile is laid through a district bordered closely by cesspools and privies there are opportunities for contamination, for the tile is naturally placed below the surface of the ground water table in order to prevent a loss of the flowing well water on the way to the receiving well, and the rapid current through the tile naturally draws in more or less water from the bordering district.

WATER-WORKS.

In the table of water-works supplies given below the population of the town as well as the source of supply and ownership of water-works has been given, but it should not be inferred that the number of actual users of public water supplies approximates that of the populations of the cities and villages, for this is the case in only a few of the cities outside of the metropolis, Detroit. On the basis of the number of taps reported it is estimated that in the cities with a population between 10,000 and 100,000 only about two-thirds of the people are connected with the public supply, and in towns of less than 10,000 population one-half or less are thus connected. The probable actual users of public supplies are estimated to aggregate about 775,000, or 32 per cent of the entire population of the State in 1900 (2,420,982), while the aggregate population of towns and institutions provided with water-works reaches 1,150,000, or nearly half the population of the State. Of the actual users of water-works supplies nearly 600,000, or about 24 per cent of the population of the State, are supplied from surface water, leaving less than 200,000 supplied from water-works drawing from wells. But of those not connected with the public supplies there are probably not more than 20,000 who depend upon surface water, including springs, while about 1,625,000, or two-thirds of the State's inhabitants, depend upon private wells.

In the matter of ownership and control it will be observed that the great majority of the water-works are municipal and that only a few of the smaller towns are controlled by private companies, Ann Arbor being the largest city whose water-works are under private management. Many cities in which the water-works were constructed by private companies have, within the past ten years, purchased the plants and there is nearly unanimous expression of satisfaction with the result of the change to municipal ownership. Nearly all the State institutions are supplied by independent water-works systems, the important exceptions being the State University at Ann Arbor and the State Normal Colleges at Ypsilanti, Mt. Pleasant and Kalamazoo.

There are a number of villages in which a partial distribution system has been installed for domestic use and others where it has been installed solely for fire protection by private arrangement independent of municipal action, the persons benefitted being either part owners of the supply and plant or purchasers at a stipulated rental. There are also a number of towns not included in the list which have provided cisterns and fire engines, hose, etc., as a means of fire protection, but have not built a distribution system. It was thought best to restrict the table of water-works to the towns in which a distribution system has been installed.

From data presented in the Manual of American Water-works it appears that about 100 Michigan cities and villages have made special provision for a fire pressure above the ordinary pressure of the water-works systems, and in several cases a special steam fire engine is held ready for use. The fire pressure in the various cities ranges from about seventy-five pounds to 160 pounds per square inch, while the ordinary pressure runs from about twenty pounds to seventy-five pounds. Acknowledgements are made to the Manual of American Water-works for a considerable number of data presented in the table below, but for a majority of the cities and villages the data have been obtained directly from officials or residents.

MUNICIPAL AND INSTITUTIONAL WATER SUPPLIES.

Town.	Population 1900.	Owner.	Source.	Remarks.
Adrian	9,654	P.	S. Raisin R.	Mechanical filter.
Adrian Home for Girls	*400	St. & C.	Drift wells	Adrian WW for fire and sprinkling.
Agricultural College	†800	St.	RW 300 feet	From sandstone.
Albion	4,519	M.	RW 110–176 feet	From sandstone.
Algonac	1,216	M.	St. Clair River	
Allegan	2,667	M.	Drift well	On river bank.
Alma	2,047	C.	Pine River	Hires pumping; chiefly for fire and sprinkling.
Alpena	11,802	M.	Lake Huron	New works planned.
Ann Arbor	14,509	P.	DW 8–30; 75 to 150 feet	Flowing wells; shallow without clay cover.
Armada	863	M.	DW, 94 feet	Flowing.
Atlantic Mine	†3,000	P.	Creek and well	Partial domestic supply from well.
AuSable	1,116	M.	Lake Huron	
Bad Axe	1,241	M.	RW, 200 feet	From sandstone.
Baldwin	388	C.	Drift well	Railroad well furnishes partial supply.
Bangor	1,021	M.	Drift well 60 feet	
Baraga	1,185	P.	Keweenaw Bay	
Battle Creek	18,563	M.	Goguac Lake	Change to sandstone wells contemplated.
Bay City	40,747	M.	Saginaw Bay	Two pump stations, one at shore, the other through conduit, from 3.5 miles off shore.
Bay Mills	†1,000	P?.	Whitefish Bay	
Bay Shore	350	P?.	Lake Michigan	Only partial supply.
Beacon	†1,500	M?.		Hydrants for fire.
Belding	3,288	C.	Flat River	Hires pumping for fire.
Bellaire	1,157	P.	Stream and drift well	Flowing well.
Benton Harbor	6,562	M.	Drift well, 43–80 feet	
Bessemer	3,911	M.	Springs and impounded water	Springs for domestic use.
Big Rapids	4,686	M.	Muskegon River	Flowing wells discontinued.
Birmingham	1,170	M.	Drift well, 45 feet	Flowing.
Blaney	†300	P.	Creek	Operated by Lumber Company.
Boyne City	*2,453	M.	Springs	Gravity system.
Buchanan	1,708	M.	Drift well	Changes pending.
Cadillac	5,997	P.	Little Clam Lake	Also village wells with pumps.
Capac	547	M.	Rock well, 100 feet	From sandstone.
Caro	2,006	P.	Springs	
Carson	906	M.	Creek	Fire protection only.
Carsonville	400	P.	Drift well	Partial supply from mill well.
Casnovia	277	M.	Impounded water	Fire protection.
Cassopolis	1,330	M.	Stone Lake	
Cedar Springs	950	M.	Creek	Chiefly fire protection.
Centerville	645	P.	Drift well, 10 feet	
Central Lake	1,307	P.	Springs	Gravity system.
Charlevoix	2,079	M.	Lake Michigan	Wells not in use.
Charlotte	4,092	M.	Drift well, 80 feet	
Cheboygan	6,489	M.	Rock well 400 feet	Water from limestone.
Chelsea	1,635	M.	Drift well, 25 feet	
Chesaning	1,244	M.	River and wells	Flowing wells.
Clare	1,326	P.	River and wells	
Clinton	1,038	P.	Raisin River	Fire protection to business part, pumped by a woolen mill.
Coldwater	6,216	M.	Drift well, 50 feet	
Coldwater State School	†250	St.	Drift well, 35 feet	
Columbiaville	457	P.	Flint River	
Constantine	1,226	M.	Fawn River	
Coopersville	660	M.	Drift well, 92 feet	Flowing.
Corunna	1,570	M.	Rock wells, 75–100 feet	Sandstone.
Croswell	606	M.	Black River	Fire protection.
Crystal Falls	3,231	M.	Impounded water	
Decatur	1,356	M.	Drift well, 125 feet	
Delray	4,573	Det.	Detroit River	
Detroit	285,104	M.	Detroit River	
Dollar Bay	†1,500	P?.		Operated by L. Sup. Min. Co.; partial distribution for employees.
Dowagiac	4,151	M.	Drift wells, 47–100 feet	Flows from deeper wells.
Durand	2,134	M.	Drift wells, 40–75 feet	

MUNICIPAL AND INSTITUTIONAL WATER SUPPLIES—*continued.*

Town.	Population 1900.	Owner.	Source.	Remarks.
Eagle	142	M?.....	Drift well.....	
East Jordan	1,205	M.....	Drift wells, 75–105 feet.....	Flowing.
East Tawas	1,736	M.....	Lake Huron.....	
Eaton Rapids	2,103	M.....	Rock well, 65 feet.....	Sandstone.
Eau Claire	281	M.....	Drift well.....	Partial distribution.
Edmore	642	M.....	Drift wells.....	Chiefly fire protection.
Elk Rapids	1,733	M.....	Elk Lake.....	
Eloise, Wayne Co. Infirmary	1,200	WC....	Stream for fire; DW for drinking.	
Escanaba	9,549	P.....	Little Bay de Noc.....	
Evart	1,360	M.....	Drift well, 15 feet.....	
Ewen	†500	M.....	Drift wells, 208–224 feet.....	Flowing.
Fairgrove	400	M.....	Impounded water.....	
Farwell	535	M.....	Spring brook.....	
Fenton	2,408	M.....	Rock well, about 120 feet.....	
Flint	13,103	M.....	Flint River.....	Many wells in sandstone.
Flint School for Deaf	500	St. & C.	Well for drinking; city supply for baths, etc.....	
Flushing	900	M	Flint river.....	Fire protection
Ford	*1,372	C.....	Detroit River.....	Water pumped by Ford Mfg Co.
Fowler	426	M?.....	Drift well.....	
Frankfort	1,465	M.....	Drift wells, 90–150 feet.....	
Fremont	1,331	M.....	Drift wells, 225 feet.....	Flowing.
Fulton	275	M.....	Drift well.....	Partial system.
Garden	465	M.....	Rock wells, 104–220 feet.....	Partial system.
Gaylord	1,561	M.....	Drift well, 80 feet.....	
Gladstone	3,380	M.....	Little Bay de Noc.....	
Gladwin	775	M.....	RW, 165–180 feet, and river.....	River for emergency.
Grand Haven	4,743	M & P..	Drift wells, 20–30 feet.....	Both systems from shallow wells near Grand River.
Grand Ledge	2,167	M.....	Rock wells, 90–130 feet.....	Flows from sandstone, siphoned to reservoir.
Grand Marais	2,000	M.....	Lake Superior.....	
Grand Rapids	87,565	M.....	Grand River.....	Much spring water sold for drinking.
Grand Rapids Mich. Soldiers Home	1,250	St.....	Springs and impounded water...	Springs for drinking; impounded waters for boilers and fire.
Grandville	457	M.....	Rock wells.....	Flowing wells with fire plugs.
Grayling	†1,800	P.....	Au Sable River.....	Operated by a lumber company.
Greenville	3,381	M.....	Drift well, 40 feet.....	Flowing.
Grosse Pt Tp (several vill's).	*2,928	P.....	Lake St. Clair.....	Pumping station for villages; also many individual intake pipes.
Haakwood	†100	P.....	Drift well.....	Flowing well; piped to houses of Haak Lumber Company.
Hamtramck	1,559	Det....	Detroit River.....	Supplied by Detroit.
Hancock	4,050	M.....	Filter gallery by Portage Lake...	
Harbor Beach	1,149	M.....	Lake Huron.....	
Harbor Springs	1,643	M.....	Drift wells, 64–320 feet.....	Flowing.
Harrison	647	M.....	Small lake.....	
Hart	1,134	M.....	Drift wells, 112–152 feet.....	Flowing.
Hartford	1,077	M.....	Drift well, 40 feet.....	
Hastings	3,172	M.....	Drift well, 35 feet.....	
Hesperia	474	M? & P	White River for fire, flowing wells for drinking.....	Flowing well water piped at private expense for domestic use.
Hillman	253	M.....	Thunder Bay River.....	
Hillsdale	4,151	M.....	Small lake.....	
Holland	7,790	M.....	Drift wells, 25–40 feet.....	
Holly	1,419	M.....	DW, 23–47; 140–180 feet.....	
Houghton	3,359	M.....	Springs.....	High pressure and low pressure reservoirs.
Howard City	1,398	M.....	Creek for fire, DW for drinking.	
Howell	2,512	M.....	DW, 70 feet.....	
Hudson	2,403	M.....	DW, 70 feet.....	
Imlay	1,122	M.....	RW, 162–223 feet.....	Water brackish, from sandstone.
Indian River	†500	P.....	DW.....	Flowing wells piped to many dwellings by natural pressure.
Ionia	5,209	M.....	Rock well and springs.....	Wells in sandstone.

MUNICIPAL AND INSTITUTIONAL WATER SUPPLIES—*continued.*

Town.	Population 1900.	Owner.	Source.	Remarks.
Ionia State Asylum	.....	St.....	RW, 359 feet, also springs.....	
Iowa State Reformatory....	700	St.....	Springs.....	Supplies part to Asylum.
Iron Mountain.....	9,242	P.....	Filter gallery by lake.....	Water flows toward lake.
Iron River.....	1,482	M?.....	Iron River.....	
Ironwood.....	9,705	P.....	Montreal River.....	
Ishpeming.....	13,255	M.....	Small lake.....	
Ithaca.....	2,020	M.....	Rock well, 600 feet.....	Sandstone at 300 feet.
Jackson.....	25,180	M.....	Rock wells, 200–400 feet.....	Water from sandstone.
Jackson State Penitentiary..	†800	St.....	Rock well, 200 feet for drinking, river for boiler use..	
Jennings.....	800	P.....	Lake Missaukee.....	Chiefly fire protection.
Jonesville.....	1,367	M.....	Drift well, 56, rock well, 60 feet..	All flow.
Kalamazoo.....	24,404	M.....	Drift wells, 31 and 80–120 feet..	Deep wells flow.
Kalamazoo State Asylum...	2,000	St.....	Infiltration well, 30 feet.....	From springs, and nearby creek.
Kalkaska.....	1,304	M.....	Boardman River.....	
Kingston.....	286	M.....	Rock well, 217 feet.....	Rock at 150 feet.
Lake City.....	816	P.....	Lake Missaukee.....	
Lake Linden.....	2,597	M.....	Rock well and creek.....	Flowing wells from sandstone.
Lake Odessa.....	1,037	M.....	Drift well, 50 feet.....	Flowing.
L'Anse.....	620	M.....	Spring fed creek.....	Gravity system.
Lansing.....	16,485	M.....	Rock wells, 28–350 feet.....	Wells in sandstone; some flow.
Lansing Industrial School...	800	St.....	Rock well, 600 feet.....	
Lapeer.....	3,297	M.....	Rock wells, 250–290 feet.....	Wells in sandstone.
Lapeer State Home for Feeble-Minded.....	†800	St.....	Rock well, 337 feet.....	Sandstone at 146 feet.
Laurium.....	5,643	C.....	Lake Superior.....	Pumping by mining company.
Lawrence.....	598	M.....	Drift well, 60 feet.....	
Leslie.....	1,114	M.....	Rock well, 180 feet.....	Flowing wells from sandstone.
Lewiston.....	†800	M.....	Twin Lake.....	
Lexington.....	619	M & P..	Drift wells, 20–25 feet.....	Flowing wells fill fire cisterns; also piped at private expense to dwellings.
Lowell.....	1,736	P.....	Drift wells.....	
Ludington.....	7,166	M.....	Lake Michigan.....	
Lyons.....	656	M.....	Grand River.....	For fire and sprinkling.
Mackinac Island.....	665	P.....	Lake Huron.....	
Manccelona.....	1,226	M.....	Drift well, 65 feet.....	
Manistee.....	14,260	M.....	Drift well, 100 feet.....	Wells by river bank.
Manistique.....	4,126	M.....	Indian Lake.....	Village has flowing wells from limestone; waterworks system from lake, installed 1906.
Manton.....	895	M.....	Small creek.....	Chiefly fire protection.
Marcellus.....	1,025	M.....	Drift well, 50 feet.....	
Marine City.....	3,829	M.....	St. Clair River.....	
Marlette.....	996	M.....	Rock well, 60 feet.....	Wells from sandstone.
Marquette.....	10,058	M.....	Lake Superior.....	
Marquette State Prison.....	300	St.....	Small stream.....	
Marshall.....	4,370	M.....	Rock well, about 100 feet.....	From sandstone.
Mason.....	1,828	M.....	Rock wells, 67–172 feet.....	Flows from sandstone.
Menominee.....	12,818	P.....	Green Bay.....	
Midland.....	2,363	M.....	Chippewa River.....	
Milan.....	1,141	C.....	Saline River.....	Partial system for fire.
Milford.....	1,108	M.....	Infiltration wells.....	Wells on river bank.
Millington.....	638	M.....	Rock wells, 187–200 feet.....	Sandstone at 110 feet.
Mio.....	150	P.....	Spring creek.....	Chiefly fire protection.
Monroe.....	5,043	P.....	Lake Erie.....	
Montague.....	998	M.....	Spring-fed brook.....	Chiefly fire protection.
Mt. Clemens.....	6,576	M.....	Drift well by stream.....	
Mt. Pleasant.....	3,662	M.....	Drift wells, 20 to 30 feet.....	Flowing.
Mt. Pleasant Indian School..	†368	U. S....	Drift well.....	
Muir.....	556	M.....	Springs.....	Partial supply for drinking.
Munising.....	2,014	M.....	Springs and Lake Superior.....	Lake Superior for emergency.
Muskegon.....	20,818	M.....	Lake Michigan.....	Infiltration wells.
Nashville.....	1,164	M.....	Rock well, 300 feet.....	Chiefly fire and sprinkling; flowing wells from sandstone.
Negaunee.....	6,935	M.....	Teal Lake.....	
Newaygo.....	1,172	M.....	Drift well, 20 feet.....	

MUNICIPAL AND INSTITUTIONAL WATER SUPPLIES—*continued.*

Town.	Population 1900.	Owner.	Source.	Remarks.
New Baltimore	922	M.	Lake St. Clair	
Newberry	1,421	M.	Drift well, 100 feet	
Newberry State Asylum	600	St.	DW, 186–245 feet, RW, 457 feet.	Water chiefly from drift wells; limestone with water at 320 feet.
Niles	4,287	P & M.	Lake for private waterworks; drift well, 110 feet for city	Private system installed earlier, still in use.
North Muskegon	513	M.	Rain Lake	
Northville	1,755	M.	Springs	Gravity system.
Norway	4,170	M.	Impounded water	Also supplies Vulcan.
Novi	†100	P.	Drift well	Partial system.
Onaway	1,204	M.	Rock wells, 190–235 feet	Wells from limestone.
Ontonagon	1,267	M.	Lake Superior	
Oscoda	1,109	M.	Lake Huron	
Otsego	2,073	M.	Kalamazoo River	Fire protection only.
Ovid	1,293	M.	Drift well, 24 feet	
Owosso	8,696	M.	Drift well, about 70 feet	Some flowing wells.
Oxford	1,172	M.	Drift well, 85 feet	
Palmer	799	P.	Springs and wells	Partial system; for domestic supply.
Paw Paw	1,465	M.	Drift well, 60 feet	
Petoskey	5,285	M.	Drift well, 22 feet	
Pewaymo	446	M.	Drift wells	
Pentwater	1,061	M.	DW, 16-24 ft and Lake Michigan.	Lake for fire and sprinkling.
Pinconning	729	M.	Impounded water	Private flowing wells.
Plainwell	1,318	M.	Kalamazoo River	For fire protection.
Plymouth	1,474	M.	Springs	Gravity system.
Pontiac	9,769	M.	Drift well, 175 feet	
Pontiac State Asylum	†1,450	St.	Drift wells, 100–125 feet	
Port Huron	19,158	M.	St. Clair River	
Portland	1,874	M.	Drift wells, 38–50 feet	
Quincy	1,563	M.	Drift wells, 32–35 feet	
Quinnesec	†600	M.	Mine water	Chiefly fire protection.
Rapid River and Masonville.	†1,200	M.	Rock well, 275 feet	For fire protection; flowing wells from sandstone.
Reading	1,096	M.	Rock well, 56 feet	Flowing wells from sandstone.
Reed City	2,051	M.	Ponds, springs and drift wells	Flowing drift wells.
Reese	416	M.	Drift wells	
Republic	†2,500	M ?.	Springs and lake	Installed in 1906.
Richmond	1,133	M.	Drift well, 120 feet	Also supplies Lenox.
River Rouge	1,748	Det.	Detroit River	Supplied by Detroit.
Rochester	1,535	M.	Drift wells, 60–80 feet	Flowing wells; gravity system.
Rockford	711	M.	Rouge River	Mainly for fire protection.
Rockland	†1,000	P.	Springs	Water supplied to school and a few dwellings by windmill.
Rogers	544	M.	Drift well, 60 ± feet	For fire protection.
Romeo	1,580	M.	Drift well, 20 feet	
Roscommon	465	M.	Small stream	Chiefly fire protection.
Rose City	300	P.	Drift wells, 60-200 feet	Flowing wells piped by natural pressure to residences.
Saginaw	42,345	M.	Saginaw River	Numerous wells for drinking.
St. Clair	2,543	M.	St. Clair River	
St. Ignace	2,271	M.	Lake Huron	
St. Johns	3,388	M.	Rock wells 222–574 feet	Wells in sandstone.
St. Joseph	5,155	M.	Lake Michigan	
St. Louis	1,989	M.	Pine River	Chiefly for fire; flowing wells (private), for domestic use.
Sault Ste Marie	10,538	M.	Whitefish Bay	
Scottville	554	M.	Drift well, 54 feet	
Shelby	1,081	M.	Drift well, 125 feet	
Sheridan	437	M.	Small lake	Chiefly fire protection.
South Haven	4,009	M.	Lake Michigan	Filter galleries in lake bed.
Sparta	1,126	P.	Drift well and stream	For fire protection.
Stambaugh	695	M.	Iron River	
Standish	829	M.	Wells and streams	For fire protection.
Stanton	1,234	M.	Drift wells, 30 feet	Flowing.
Stevensville	250	M.	Springs	For fire protection.
Sturgis	2,465	M.	Drift well, 140 feet	
Suttons Bay	398	P.	Impounded water	Fire protection only.

MUNICIPAL AND INSTITUTIONAL WATER SUPPLIES—*continued.*

Town.	Population 1900.	Owner.	Source.	Remarks.
Tecumseh	2,400	M.....	Drift well, 35 feet	
Thompsonville	893	M.....	Drift wells	Partial system.
Three Oaks	994	M.....	Drift wells, 76–86 feet	
Three Rivers	3,550	M.....	Drift wells, 75–108 feet	Flowing.
Traverse City	9,407	M.....	Grand Traverse Bay	Many private flowing wells from drift deposits.
Traverse City State Asylum	†1,450	St.....	Drift wells, 100–190 feet	Flowing.
Trenton	1,167	M.....	Detroit River	
Union City	1,514	M.....	Drift wells ?	
Vassar	1,832	M.....	Cass River and wells	Flowing wells from sandstone.
Vicksburg	972	M.....	Drift well, 60 feet	
Vulcan	†2,000	.....	.....	Supplied from Norway.
Wakefield	1,191	M.....	Sandy Lake	Chiefly fire protection.
Watervliet	717	M.....	Drift wells	For fire protection.
West Branch	1,412	M.....	Drift wells	Gravity system from flowing wells to be installed in 1906.
Weston	†275	P.....	Drift well	Fire protection for business houses, from elevated tank.
White Cloud	595	M.....	White River	
Whitehall	1,481	M.....	Drift well, 67 feet	Flowing.
Williamston	1,113	P ?....	Mill pond	Fire hydrants on main street.
Woodland	*320	M.....	Drift wells	Partial system.
Woodmere	5,034	Det....	Detroit River	Supplied from Detroit.
Wyandotte	5,183	M.....	Detroit River	
Yale	1,125	M.....	DW, 85–90 and 220 feet	Flowing.
Ypsilanti	7,378	M.....	Drift well 65 feet	Flowing.
Zeeland	1,326	M.....	Drift well, 20 feet	

*Population in 1904, from State Census.
†Population in 1906, from officials of the institution.
(a) The abbreviations given under the column for ownership stand for the following: "P" for Private or Company; "M" for Municipal; "C" for Co-operative; "St." for State; "U.S " for United States; "WC" for Wayne County; "Det" for Detroit. Under the column for source "DW" stands for drift well or drift wells, and "RW" for rock well or wells.

ANN ARBOR, MICH., U. S. Geological Survey.

MICHIGAN WATER SUPPLIES.

VICTOR C. VAUGHAN.

MR. CHAIRMAN AND GENTLEMEN: The Hygienic Laboratory of the University of Michigan was opened in October, 1888. The establishment of this laboratory resulted from the activity of the Michigan State Board of Health. This Board memoralized the Board of Regents, asking that the Legislature be requested to make an appropriation for a State Laboratory of Hygiene to be placed under the control of the Board of Regents and to become a part of the University of Michigan. The memorial stated the objects of the laboratory to be as follows:

(1) Original investigations into the causation of disease.

(2) The examination of food and drink for the health officers of the State.

(3) The instruction of students in hygiene and bacteriology.

As director of this laboratory since its foundation I have always held in mind the above stated objects and have endeavored to direct the work of the laboratory along these lines.

The health officers and other village and city authorities have availed themselves of the facilities of the laboratory in the examination of drinking waters used by their communities and up to the present time more than one thousand samples of water have been received from officials and examined. Some of these have come from other states and will not be included in the tabular statements given in this paper.

The method of examination differs from that practiced elsewhere and needs to be briefly stated here. The waters are received in sterilized receptacles and immediately on receipt the examination is begun.

The number of bacteria per cubic centimeter is determined by plate cultures. Two sets of plates are made, both of agar; one is grown at ordinary room temperature and the other at 37° C. in the incubator. Early in our work we discovered that many of the ordinary water bacteria do not develop at the temperature of the human body (37° C.), while all bacteria pathogenic to man grow best at this temperature. Therefore an abundant growth on the plates kept at room temperature and a slight growth on the plates kept at 37° C. indicates the presence of many saprophytic organisms and the presence of but few, if any, that are pathogenic. At room temperature the saprophytic crowd out the pathogenic organisms, while at the higher temperature the reverse is true. It will be seen that this test is in and of itself of great value in arriving at a correct estimate of the danger that lies in the water.

In the second place beef tea tubes are inoculated with the water and these tubes are kept in an incubator, the temperature of which is kept constantly at from 38° to 40° C. Usually six tubes are so inoculated, the amounts of water in these inoculations running from 0.05 to 1.00 c. c. These tubes are kept in the incubator for twelve hours, at the expiration of which time, 2 c.c. is injected intraabdominally into rats or guinea pigs. If the tubes contain a pathogenic germ the animal is dead in twelve hours. As soon as the animal dies it is opened aseptically and

plates made from the heart's blood. Within another twelve hours these plates have developed and cultures are made from the colonies. For these plates litmus agar is used for the purpose of distinguishing between bacteria of the colon group and those of the typhoid group. Moreover the colonies on the plates made from the heart's blood are grown in special media for the purpose of more exact differentiation. However, I will not go further into this point in this paper.

While this bacteriological investigation is being carried on, the ordinary chemical analysis is made.

The cities and villages of Michigan are supplied with (1) well water, (2) waters from small lakes, (3) waters from the great lakes, (4) waters from streams, and (5) waters from springs.

WELL WATERS.

The following table gives the results of the examinations of well waters:

TABLE I.

Well Water and City Waters from Wells.

Place.	No. sample.	Ammonia.		Cl.	No. of Germs.	Effect on animals.
		Free.	Alb.			
Allegan	3	.282	.256	32.	121	.....
Adrian	6	.123	.096	16.7	2,857	4+
Ann Arbor	15	.420	.065	14.8	502	14 + of 36
Attica	1	.100	.170	9.2	1,560	1+
Amasa	5	.126	.238	2.6	702	1+
Alma	5	.226	.122	14.58	1,960	3+
Brown City	1	.220	.096	8.	400	.....
Bay City	5	.130	.101	6.65	3,985	1+
Battle Creek	13	.180	.084	8.7	1,894	6 + of10
Bugleton	1	.080	.05	14.8	300	.....
Burr Oak	1	.030	.050	9.9	100	.....
Coldwater	7	.111	.078	10.1	540	1+
Climax	1	.206	.084	4.5	105	.....
Caro	1	.19	.12	6.	10	.....
Charlevoix	1	0.9	.22	16.5	.....	.....
Cassopolis	1	.01	.01	33.	5	.....
Charlotte	4	.007	.035	17.5	2,225	.....
Corunna	1	.008	.004	4.	1,560	.....
Deerfield	1	.508	.158	695	898	1+
Dowagiac	2	.018	.115	1.8	47	1+
East Lake	2	0.68	.089	23.37	2,920	.....
Escanaba	3	.045	.122	14.8	130,025	1+
East Tawas	1	.005	.062	9.9	22	.....
Eaton Rapids	3	.016	043	30.	1,560	.....
Eloise	1	.130	.120	37.	16,680	1+
Flint	1	.011	040	5.	100	1+
Freemont	2	.....	.....	.....	568	.....
Flushing	6	.012	.080	35.9	870	3+
Grand Rapids	11	007.	.115	12.2	597	1+
Gladwin	1	.374	.044	11.8	63	.....
Gladstone	5	.030	.410	7.5	17,770	2+
Greenville	1	1.46	.40	38	550	1+
Grass Lake	1	.001	.001	9.	300	.....
Gregory	1	.050	.060	11	5.740	1+
Genoa	2	.....	.....	.....	6,150	2+
Hastings	1	.20	.11	18.	850	.....
Hancock	1	.01	.01	53	2,500	.....
Holland	7	.217	.111	21.1	182	1+
Howell	6	.083	.260	19.6	1,707	.....
Holt	1	.030	.050	24.7	2,020	.....

Well Waters, Etc.—Con.

Place.	No. sample.	Ammonia.		Cl.	No. of Germs.	Effect on animals.
		Free.	Alb.			
Irvine	1	.....	.....	.....	3	.....
Imlay City	1	.15	.2	20	24,000	.....
Iron Mountain	12	.558	.802	24.5	2,110	9+
Ironwood	7	.103	.162	22.8	674	3+
Ida	1	.910	.120	155	2,000	.....
Jackson	1	.002	.007	205	81,000	1+
Kalamazoo	25	.041	.068	7.4	3,296	8+
Kalkaska	4	.....	.....	.....	11,385	.....
	1	.020	.200	9.9	365	.....
Laporte	2	.....	.....	.....	394	.....
Lake View						
Leslie	2	.840	.912	13.2	1,522	.....
Lowell	2	.035	.450	.400	6,512	1+
Lawrence	1	.030	.040	10.5	.....	.....
Lansing	10	.07	.037	10.3	712	2+
	2	.195	.129	19	625	.....
Mendon						
Merrill	1	.055	.010	4.3	10	.....
Mackinaw Island	1	.030	.060	10.8	.....	.....
McIvor	1	.040	.240	13	24,000	.....
Manitowoc	1	.200	.090	16.5	.....	.....
Morrice	1	.04	.07	102.	600	.....
Manistee	2	.004	.078	2.2	15	.....
Manceiona	2	.011	.047	8.5	95	1+
Manchester	1	.020	.150	5.5	700	.....
Mt. Clemens	12	.060	.099	15.4	4,060	4+
Morenci	2	.005	.010	24	20	.....
Mt. Pleasant	2	.087	.070	50.6	217	.....
North Branch	1	.010	.010	62.16	72,000	.....
Northville	2	.573	.368	5.1	2,925	1+
Norway	1	.005	.010	.500	6	.....
Nashville	1	.020	0.20	6	4,800	.....
Oak Grove	1	.030	.010	4	400	1+
Okemos	4	.092	.257	43.1	92	1+
Ontonagon	2	.....	.....	.....	73	.....
Pontiac	15	.185	.231	24.8	370	4+
Port Huron	3	.007	.126	8.8	108	2+
Petoskey	12	.048	0.66	8.53	7,421	.....
Parma	1	.058	1.24	100.6	1,234	.....
Petersburg	1	.720	.160	7.00	—160	1+
Romeo	1	.020	.030	9.9	15	.....
Sherwood	3	.092	.41	17.6	1,160	2+
Schoolcraft	1	.....	.010	4.	2,400	.....
Saginaw	8	.113	.197	95.8	437	1+
St. Johns	4	.073	.093	18.7	2,900	1+
Springwells	1	.040	.140	99	.....	1+
Shelby	2	.010	.090	37.1	.....	1+
Sparta	1	.100	.100	49.5	1,250,000	.....
Stockbridge	1	.350	.220	2.2	6,000	.....
Three Rivers	8	.130	.075	5.2	21	.....
Tecumseh	2	0.18	.049	10.	1,220	.....
Torch Lake	2	.....	.....	.....	1,270	1+
Traverse City	6	.008	.008	3.9	933	1+
Tawas City	.....	.680	.285	520	.....	.....
Union City	3	.009	.017	18.2	877	.....
Utica	1	.016	.013	6.6	.....	.....
Wyandotte	4	.133	.171	31.1	625	2+
Wells	3	.270	.046	7	.....	.....
Yale	3	.220	.068	25.2	11,258	2+
Ypsilanti	2	215	.062	22.7	.....	.....
Average	322	.126	.142	25.3	.....	107+
Total	300	.....	.....	.....	4,261	.....

Certain things in this table need explanation. Fifteen samples of Ann Arbor water were examined chemically, but thirty-six samples were examined bacteriologically, and of the thirty-six, fourteen contained bacteria that killed animals. Thirteen samples of Battle Creek water were examined chemically, while only ten were examined bacteriologically, and six out of ten contained bacteria that killed animals.

WATERS FROM SMALL LAKES.

Table II gives the results of the examination of waters from small lakes.

TABLE II.

Waters from Small Lakes.

Place.	No. sample.	Ammonia.		Cl.	No. of Germs.	Effect on animals.
		Free.	Alb.			
Battle Creek	10	.051	.123	6.3	15,183	5+
Cassopolis	1	.070	.100	7.	640	2+
Elk Rapids	7	.204	1.04	5.7	1,185	5+
Ishpeming	14	.150	.048	4.3	.....	5+
Ironwood	1	.018	.300	1	150	.....
Iron Mountain	6	.161	.294	4	23	.....
Island Lake	2	.202	.222	16.5	549	1+
Lake City	1	.154	.280	3	124	.....
Manistique	5	.058	.199	8	.....	1+
Norway	1	.004	.010	9	20	1+
Negaunee	6	.220	.454	20.2	1,108	4+
Pontiac	2	.198	.326	9.8	15	.....
Sturgis	1	.050	.250	4	50	.....
Torch Lake	1	.....	.....	.....	.....	1+
Average	58	.124	.175	7.3	1,731	25+

WATERS FROM THE GREAT LAKES.

I have included among the waters of the Great Lakes those from the connecting rivers, such as the St. Clair and Detroit rivers. It will certainly be understood that most of these cities take their supplies not directly from the Great Lakes, but from some bay or harbor, which is often polluted by the city itself.

TABLE III.

Waters from the Great Lakes.

Place.	No. sample.	Ammonia.		Cl.	No. of Germs.	Effect on animals.
		Free.	Alb.			
Baraga	3	.310	.226	6.5	410	3+
Bay City	3	.235	.513	403.3	400	2+
Detroit	6	.012	.047	14.8	18	2+
Escanaba	32	.049	.084	12.8	19,330	6+
Menominee	15	.035	.092	4.3	.....	4+
Mt. Clemens	1	.040	.030	5	.....	1+
Marine City	2	.110	.070	95	.....	1+
Marquette	80	.020	.050	6	5,692	4+
Port Huron	4	.078	.161	8.6	1,600	2+
Petoskey	8	.033	.056	3.8	944	3+
St. Clair	7	.006	0.20	8	40	4+
Sault Ste. Marie	11	.074	.068	4.5	16,280	2+
Traverse City	5	.050	.066	10	12,152	2+
Wyandotte	3	.011	.228	27.5	3,090	3+
Trenton	1	.020	.012	6.6	840,000	.....
Average	181	.040	.076	15.3	12,067	39+

STREAMS.

Table IV gives the examinations of waters taken from rivers and smaller streams. Some of these constantly contain the colon bacillus and consequently kill animals. This will be seen to be true of the river waters from Alma and Adrian. Every sample of water from the stream supplying Adrian has killed animals, even after filtration. The pathogenic organism invariably found is the colon bacillus, and there have been no epidemics of typhoid at Adrian. This is quite convincing evidence that the colon bacillus does not cause typhoid.

TABLE IV.

Streams and Rivers.

Place.	No. sample.	Ammonia.		Cl.	No. of Germs.	Effect on animals.
		Free.	Alb.			
Alma	5	.088	.048	6.6	1,001	5+
Adrian	10	.071	.038	10.6	91	10+
Ann Arbor	4	.152	.084	4.4	327	1+
Calumet	2	.050	.300	168	34,000	1+
Flint	2	.075	.290	9.7	2,571	1+
Grand Rapids	11	.034	.127	8.4	16,624	5+
Ishpeming	2	.310	.750	7	.....	.....
Ironwood	8	.047	.172	3.9	699	3+
Kalamazoo	1	.200	.220	6.6	4,000	.....
Mt. Pleasant	1	.094	.208	79	3,000	.....
Petoskey	1	.700	.100	4.5	2,300	1+
Saginaw	2	.1	.180	5.4	2,750	.....
St. Louis	2	.052	.265	23	4,700	.....
Total	51	.....	.....	.....	.....	.....
Average	.....	.091	.153	15.7	5,979	27+

SPRING WATER.

Most of the springs in Michigan are surface springs and are more or less subject to bacterial contamination.

TABLE V.

Spring Water.

Place.	No. sample.	Ammonia.		Cl.	No. of Germs.	Effect on animals.
		Free.	Alb.			
Alpena	1	0.72	.174	4.64	2,880	.....
Albion	1	Trace	.010	30	500	.....
Ann Arbor	10	.0386	.102	5.89	557	.....
Caro	1	.260	.010	3.3	87	.....
Grand Rapids	2	.076	.044	4.2	70	.....
Hart	1	.030	.120	9.9	36,000	*+
Iron Mountain	2	.205	.303	.7	4	.....
Kalamazoo	1	.010	.010	5.1	600	.....
Mt. Clemens	1	.030	.080	26.4	27,500	.....
Negaunee	2	.035	.080	3	80	+
Norway	2	.230	.150	27.15	1,000	.....
Petoskey	1	.020	.080	29.5	1,940	.....
Shelby	1	.....	.....	.....	.....	.....
Thompson	2	.049	.166	130	215	.....
Traverse City	1	.020	.020	2.5	4,200	+
Average	28	.072	.088	8.8	1,309	3+

*This germ count not included in average.

CISTERN WATER.

Six samples of cistern water were examined; chemical analysis of three of these show an average Free NH_3 of 1.001 parts albumenoid, NH_3 of .558 pts. and Cl. as Nacl=6. The bacteriological examination showed an average of 85,040 per c. c. Culture were fatal to animals in five of the six cases.

ARTESIAN WATER.

Nine samples were examined. The average chemical composition of eight was as follows: Free NH_3=0.165 pts. Alb. NH_3 0.092. The average chlorine would be valueless as the highest was 990 pts. and the lowest 1.32. The bacteriological examination showed from 80 to 56,400 per c. c. In but one water were germs absent. Cultures killed in four cases—in two of these B. coli was found.

SUMMARY.

In concluding I will separate the chemical from the bacteriological results. Tabulating the former we have the following:

TABLE VI.

Kind of Water.	No. of Samples.	Ammonia.		Cl.
		Free.	Alb.	
Well water	322	.126	.142	25.3
Waters from small lakes	58	.124	.175	7.3
Water from great lakes	181	.040	.076	15.3
Waters from streams	51	.091	.153	15.7
Spring waters	28	.072	.088	8.8
Cistern waters	3	1.011	.558	6.0
Artesian waters	8	.164	.092	.....

It will be seen from the above that the waters of the Great Lakes make the best showing, so far as both free and albuminoid ammonia go and the cistern waters the worst. Indeed the cistern waters were the most filthy of all examined. It should be said that these waters were from neglected cisterns and it was supposed by the families using these waters that they were to be employed only in daily ablutions, but children and roomers had washed their teeth with these waters and occasionally drank them when the drinking water pitcher was empty. In one family every person under thirty years of age, six in number, acquired typhoid in this way. Contamination from a near-by privy vault was evident. It will be understood that these figures do not indicate the composition of the waters in either the small or great lakes, but do show the composition of such waters as locally contaminated. The artesian waters were from wells recently opened and much of the organic contamination probably came from the surface.

Bacteriologically 300 samples of well water showed an average of 4,261 bacteria per c. c. and 107 (38 per cent) of these contained bacteria that killed animals.

Fifty-eight small lake waters gave an average of 1,731 bacteria per c. c., and 25 (43 per cent) of these contained bacteria that killed animals.

One hundred and eighty-one great lake waters had an average of 12,067 bacteria per c. c. and 39 (21 per cent) of these contained bacteria toxicogenic to animals.

Fifty-one samples of water from streams gave an average of 5,979 bacteria per c. c. and 27 (53 per cent) of these contained toxicogenic bacteria.

Twenty-eight samples of spring water gave an average of 1,309 bacteria per c. c. and 3 (10 per cent) of these contained toxicogenic bacteria.

Five (83 per cent) of the cistern waters contained toxicogenic bacteria and 3 of these gave an average of 85,040 bacteria per c. c. It will, of course, be understood, that these figures do not indicate the composition of the waters of well-kept cisterns any more than the figures for both the small and great lakes indicate the composition of the waters of the open lakes.

The number of bacteria in the artesian waters varied too much (from 80 to 56,400) to make an average of any value, and out of nine of these waters 4 (44 per cent) killed animals.

It will be seen from the above that spring waters, taking conditions

as they exist in Michigan today, furnish the best drinking waters, whether we look at the matter from a chemical or a bacteriological standpoint. Many of the smaller cities in Michigan are furnished with water from superficial springs. So long as the filter beds of these springs are kept from contamination these waters will remain good, but as soon as these filter beds are covered by privy vaults and cesspools these waters will no longer be safe. Many of these small cities are growing rapidly, and what they need to keep their water supplies wholesome is properly constructed sewers and compulsory house connections with these sewers. Nature has given to many localities in this State natural filter beds, which, if they had to be built artificially, would cost for each locality tens of thousands of dollars, and stupidly many localities are polluting these natural filter beds, increasing their death rate and rendering it absolutely necessary to go to a more remote water supply which will not be so safe as their original supply before it was polluted. There are probably but few cities of 20,000 or less inhabitants, in the State, that could not secure an abundant supply of wholesome water near-by if the pollution of the soil was prohibited. There is some excuse for the pollution of our streams because sewage and the waste from factories must be disposed of, but there is absolutely no excuse for the pollution of the soil about our dwellings. Whenever man builds for himself a habitation and pollutes the soil about him there, typhoid fever will sooner or later visit him. There is on this round earth no localty so salubrious that man may not contaminate it and make it unfit for his dwelling.

University of Michigan.

SHALL POLLUTION OF MICHIGAN STREAMS BE PERMITTED?

M. O. LEIGHTON.*

As the subject of this paper is in the form of an interrogation, the discussion will be commenced with a direct answer: Yes, Michigan streams must be polluted. In spite of all the preventive measures possible under ideal legislation, enacted by an ideal legislature, Michigan streams must inevitably be polluted; there is no alternative from this conclusion. Let us review the facts briefly.

The water which flows in a stream is largely derived from the land lying above. The rain falls upon the ground and either runs directly off into water courses or sinks into the ground, to reappear in the form of springs or as seepage, so that ultimately, nearly all the precipitation is drained off into rivers. It is well known that water is an excellent solvent; as it passes over and through the ground, it dissolves larger or smaller quantities of those substances with which it comes in contact. If it passes through a bed of salt, for example, it will, when it emerges, contain some of that salt, or if it encounters filthy conditions, it will contain an abnormal amount of organic matter. Therefore, it may safely be said that the character of any stream water affords an excellent record of the conditions through which it has passed.

Streams draining primeval countries carry what is known as "normal" water, or what is more popularly called "pure" water. Whatever of organic matter such water may contain, consists of the products of decay of vegetable matter. But when man moves upon that drainage area and sets up his establishments, the water draining over and through the land which he occupies must of necessity acquire characteristics which it hitherto did not possess. Such water will contain, in addition to the vegetable organic matter, the products of the decay of animal matter, and just here we have what may be called "initial" pollution.

It is but a short step from the exceedingly minute and immeasurable amount of pollution imparted to run-off waters by one inhabitant, to the large amount which must be the necessary result of drainge of the land occupied by many persons, and so it is, that we may accept the statement as final and axiomatic that no river water can remain unpolluted so long as its drainage area is inhabited. It may, of course, have so small a population per square mile, and the habits of that population may be so regulated that there will be no *measurable* effect upon the run-off; but the effect is there nevertheless.

When, however, we take up the consideration of a stream that drains a populous basin, that has cities and villages upon its banks, like most of those in which we are interested, we may be perfectly sure at the outset that just as long as those cities and villages remain there, the

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river water cannot be constantly safe for domestic consumption in its raw state. Were every one of these municipalities supplied with sewerage systems, and were the most perfect sewage disposal plants installed, this water would still be unsafe for domestic uses. The natural drainage from closely inhabited land is dangerous enough, but in addition to this there are those occasional and sometimes surreptitious pollutions which are doubly dangerous in themselves, and which inevitably occur whenever people live along the banks of a stream. If we review the history of some of our classic typhoid fever epidemics, we will recall that the ultimate cause of those epidemics was just such isolated and comparatively insignificant pollutions. The Plymouth epidemic, it will be remembered, arose from a single focus of pollution upon a sparsely inhabited drainage area. The conditions in connection with the New Haven epidemic were similar, as were those at Ithaca and Butler. No amount of city sewage purification would have prevented these epidemics. The fact that there was habitation upon the drainage area was sufficient to cause the trouble. Therefore, the pollution of streams draining occupied countries is inevitable and the water of all such streams is dangerous for domestic use in its raw state. The sooner we accept these facts, the more intelligently we can deal with the entire situation.

The admission that our streams must be polluted, does not, however, warrant the conclusion that they may, with propriety be abused. The inevitable pollution of any stream is a reasonable one. It does not affect any of the values of a water course, except that of domestic supply. Such pollution never reduces a river to a stream of liquid filth. It does not render the water a damage to industrial enterprises, nor does it kill fish, nor make the stream a general nuisance. The only damage caused (that of domestic water supply) can readily be overcome by filtration, or similar methods of purification, and the cost of such purification systems and the expense of their maintenance must be considered as a reasonable price which society must pay in return for the advantages accruing by reason of the industrial and social development upon the drainage area. Surely this is not an unreasonable price.

Therefore, it seems as though the limit beyond which pollution of streams should not proceed is that defined by what may be considered as inevitable and reasonable pollution. Under such a limit no warrant is given to cities to dump immense volumes of raw sewage into a river, nor is a manufacturing establishment justified in pouring out its millions of gallons of damaging wastes into the very streams which must be used for water supply by us and by generations yet unborn. Looking at the matter from this point of view, it is questionable whether or not an industry or a city is not justified in polluting streams up to a point which does not exceed the inevitable degree of pollution. Inasmuch as it is necessary to purify stream waters for domestic consumption, it makes little difference whether or not the pollution be the natural contaminated drainage, or the partly purified effluent of a sewage disposal plant. When, however, the amount of pollution increases so as to make the purification of the water for domestic purposes more expensive or more uncertain, such pollution must be con-

sidered as unreasonable and subject to regulation and prohibitive legislation. Filtration systems of water supply are provisions for public safety. When properly constructed and maintained they are absolute safeguards against the infectious pollution in a slightly polluted water. With the increase of pollution in the water, the safety provided becomes more and more precarious. In other words, a filter provides a wide margin of safety in the case of a slightly polluted water, but a narrow, precarious, and expensive margin in the case of a grossly polluted water. No matter how faithful or how expert the attendants in charge of a filtration system may be, there will arise occasions when the effluent of that system will not be purified as completely as the system of purification would warrant. If the water supply is only slightly polluted the danger is not great, but if, on the other hand, it is a dangerously polluted water, then the occasional lapses may and will allow infection to enter the distribution system with serious results.

The above statements indicate with a fair degree of precision the line which may be drawn between permissible or inevitable pollution and unreasonable or gross pollution. In the former case, we are helpless, but in the latter, we should be all powerful.

There are a few observations which may profitably be made concerning the efforts exerted by many authorities, and the legislation prepared and presented by them to prevent stream pollution. Many of the laws which legislatures are requested to enact are altogether unreasonable because they seek to secure that which it is not within the power of man to attain. If those interested in the pollution of streams would take the middle course or the reasonable course, and recognize the limitations by which they must be guided, they would secure immediate recognition by legislative bodies, and the commendation of society at large. A statute that recognizes these limitations, that seeks to secure reforms gradually and expediently, and that tactfully takes account of the fact that long imbued municipal and industrial habits are not to be effaced by the sounding of a trumpet, is the only one that promises success.

United States Geological Survey, Washington, D. C.

PURIFICATION OF MUNICIPAL WATER SUPPLIES.

G. S. WILLIAMS.

MR. CHAIRMAN AND GENTLEMEN: The subject of water purification here in America is a comparatively modern question. A few years ago, within our easy recollection, there were not many places where water purification was necessary, but with the growth of population the possibilities of obtaining a satisfactory supply of water from the surface of the earth became materially decreased, and we have had to resort to those methods which have been in vogue in the old world for nearly three-fourths of a century. It is only within recent years that the ground water supply of Paris, for instance, has been discovered to be seriously polluted. For many years Paris boasted of a pure spring supply which was thought beyond all possibility of being contaminated, and yet for a number of years we have noticed that Paris has had a higher death rate from typhoid fever than other European cities. The springs furnishing water come from a fissured rock, and the drainage which contributes to these springs has become polluted, and in time it has been possible for that pollution to seep through the crevices of the rock and infect the springs, and the authorities have now discontinued the use of several of these, and have substituted in their place filtered river water. They have further recently investigated American methods of water purification with a view of their application to the water of the river Seine. The record of water borne diseases is the best criterion of the water supply of a community, so far as the past is concerned, but from many sad experiences we are quite safe in saying that in these days *no* surface water supply is a safe supply. The distance to which pollution may be transmitted is dependent upon the life of the organisms which may produce infection. That life in the case of the typhoid germ is ordinarily ten days, and with occasional ones very much longer, perhaps as much as sixty days, perhaps 100, in fact we do not know how long they may live. Therefore the distance to which they may be transmitted is dependent upon their life, and their vitality at the time they may arrive in the conditions where they cause infection. It seems to me that it was pretty clearly shown that the water supply of St. Louis was being polluted by Chicago sewage after the opening of the drainage canal, for the death rate of typhoid fever increased immediately. The Supreme Court has seen fit to differ from me on that point, and perhaps I am not warranted in saying that this was the fact, but as the result of the investigation which was made, I not having, like the Court, to restrict my findings to the laws of evidence, feel quite thoroughly convinced that a very large portion of the increase of typhoid fever in St. Louis has been due to the discharge by Chicago of sewage into the drainage canal.

Now as to the means of purifying water. The best, of course, is

distillation. It necessarily kills all living organisms which may be present, as does also boiling. We have the possibility of purifying by certain chemicals, and we have the domestic filtering apparatus, which is nothing more than a fine strainer. We have nature's method, dilution, which is the reduction of the percentage of obnoxious matter that may be present in the stream, by reason of the inflow through its bed, and by its tributaries, of water which is less polluted. The pollution under these circumstances will be further decreased by the fact that a large percentage of the foreign matter which comes into the water is heavy and will settle to the bottom. Then we have purification as the result of aëration. This is an important factor under certain conditions, though not of such direct importance as was once supposed. Vegetable growths which occur in streams also play an important part in the decomposition and reduction of impurities, but all of these processes are more or less impracticable or imperfect on the large scale, so finally we come to the practical methods of purification which it is possible for municipalities to adopt. In these we have two very distinct processes, which unfortunately, are designated by the same name, "filtration," though they have scarcely any fundamental resemblance. These two processes comprise, first, the so-called natural or slow-sand method, in which the agents are wholly natural, in which we make use of bacteria themselves to get rid of other bacteria; and, second, the mechanical or chemical method in which we make use of chemicals to precipitate the impurities, or to put them in a condition where they may be strained out by passing the water through a strainer. The former method is the older and was introduced in London in 1839. The purpose of introducing it at that time was to remove turbidity. It was not to aid in the bacterial purification of water, for bacteria were then unknown, but rather to make the water more agreeable to the consumer. The effect of this method was so satisfactory that in 1856 its use was made compulsory upon the companies supplying London, except those who took water from subterannean sources. These filters were first designed by James Simpson for the Chelsea Water Company and were of practically the same type as those that are used today in the same process. They consisted of impervious basins, enclosing a system of under drains either of tile or brick, covered with a layer of gravel, which permitted the water to flow to the drains, and the gravel in turn was covered with a considerable depth of sand, the water being brought upon the top and allowed to seep through to the underdrains. In designing these filters, Mr. Simpson established the rate of filtration to be that which was about the same as the ordinary flow of water through the surface layers of the ground or about six feet per twenty-four hours, and when so designed the filters yielded about two million gallons per acre per day. After such a filter has been put in service there accumulates upon the surface a collection of impurities which is known as the mat. This covers the sand grains with slime and the bacteria are entangled and held there, to such an extent that after a while no water will go through the filter, and it is found necessary to remove a portion of this accumulation. The filter is then scraped, a thin layer of sand mixed with bacteria is removed from the surface and washed, and stored until such time as the sand bed

is reduced in thickness to a degree that is regarded no longer safe, when the bed is rebuilt. The practice of the English for years was to dig up their filters once a year, but the Americans beginning along in the 80's have shown that those ideas were wrong, and that the older a bed becomes the better it is; so that now we start these filters with a thickness of four feet of sand and run down to sixteen or twelve inches before renewing; or more frequently we run them down about eight inches at a time and then replace the sand, thus keeping the lower part of the bed undisturbed. After scraping, the water from these filters has to be wasted for a short time to give these surface layers an opportunity to form anew, and the filter should always be refilled with filtered water, which must be permitted to rise very slowly from the bottom. Care must, of course, be taken to prevent disturbing the surface, and the water must be brought upon it at all times without agitation.

The first attention to filtration in this country was when the city of St. Louis, in 1866, sent Mr. James P. Kirkwood, its engineer, abroad to study methods of water purification. At that time he found slow sand filtration in use at Berlin, Altona, Nantes, and Marseilles on the continent, and at Leicester, York, Liverpool, Edinburgh and Dublin, as well as London. He returned and presented a report which was published in 1869, but St. Louis went no farther. Great Britain had meanwhile accepted purification as a matter of course, and they thought no more of it. We over here did not feel the necessity for it generally, but as the result of Mr. Kirkwood's trip abroad there were two or three filters established in the United States. The first at Poughkeepsie in 1872, designed by Mr. Kirkwood, and the second a smaller plant, also from his designs, at Hudson, N. Y., in 1874. About that time St. Johnsbury, Vt., put in one, the designer of which is unknown. Those remained all the filters of this type in the United States until 1893. During that year the city of Lawrence, as the result of agitation after an epidemic of typhoid, built its famous filter, which was the first to be employed in a large city in this country, Lawrence having at this time 40,000 people. In 1894 Mt. Vernon, New York, put in a filter to supply a community of 11,000 people; in 1895 Ashland, Wis., as the result of a typhoid epidemic there, added another 10,000 to the users of filtered water, and the city of Milford, Mass., put in a filter, making another 10,000 so supplied. So while at the end of the period from 1872 to 1893, only about 36,000 people were supplied with filtered water in the United States, that number was more than doubled within the next five years. In 1899 the city of Albany put into service a slow sand filter, which added approximately 250,000 to the number of persons using filtered water. Since that time Philadelphia has put into service a portion of its filter plant, it being designed ultimately to supply the entire city, the full capacity of the plant to be 350,000,000 gallons per day. Washington has filters under construction which are nearly ready to put into service. Pittsburgh has filters under construction. New Haven has a plant which is going into service, and Yonkers, N. Y., has one now in service. The general cost of slow sand filters is about five dollars per person, and the cost of operation ranges from $1.25 to $4.00 per million gallons filtered. We find that 98 to 99 per cent of the bacteria are removed by this process. The more impure the water is when it goes through the filter the larger the percentage

removed. In Europe, where this process is used, and where they often deal with very impure water, typhoid fever is of such rare occurrence that a case of it is hailed with delight by the students of medicine. The death rates in American cities where filters have been introduced have shown a most remarkable drop. In Albany the death rate from typhoid fever dropped 75 per cent upon the introduction of filtered water. This water was taken from the Hudson polluted with the sewage of Schenectady only a few miles above.

It was my privilege to visit the Lawrence Experiment station in September, 1895, and I saw there sewage from the main sewer of the city of Lawrence, a city of over 40,000 inhabitants, being passed through about five feet of pea gravel at a rate of a quarter of a million gallons per acre per day, an effluent being obtained of sufficient purity to offer no offense if turned into a stream whose waters were used for any but drinking and culinary purposes, saw this effluent then passed through about five feet of sand very similar to our lake sand, at a rate of two and one-half million gallons per acre per day and saw the final effluent of such purity that the assistants in the laboratory had no hesitation in drinking it, its composition being about that of the best spring water.

So we water supply engineers have a good deal of confidence in our ability to purify moderately bad water and render it safe. There are, however, some limitations to the slow sand process. In the case of waters whose turbidity contains no clay, it is found that the slow sand filter works well, but if clay is present it soon fills the pores of the filter and cuts off the flow, and it is very difficult to remove a clay turbidity by simple sedimentation. At times in the spring when the Detroit water is turbid the suspended matter is made up of clay and sand. the sand turbidity will settle out in a few hours, but thirty days will not remove the clay. So where you have a water bearing clay it becomes almost impossible to deal with it by the slow sand process. A feature of the slow sand filter is that while turbidity may go through, it will still do its work in removing bacteria, so a turbid effluent is not an indication of defective purification with this process.

We now come to the other process, that known as the mechanical filter, sometimes spoken of as the mechanical process, sometimes known as the American method, and perhaps more properly called the rapid method. These filters appeared about 1887, and were originally designed for use in paper mills in Maine to take out of water those substances which were detrimental to the manufacture of paper. They consisted of tubs containing coarse sand through which the water was passed. The water coming out was clear and very attractive, and it was thought these filters would be a desirable adjunct to water supply systems. A great many of them were put into hotels and installed in small villages throughout the country. They removed turbidity and a good many supposed they would remove disease infection. The water was passed through this sand at very high rates of speed, 100 times as rapidly as it passed through in the slow sand process, and it was soon demonstrated that little bacterial purification resulted. The next thing that was suggested was the use of chemicals in connection with this rapid filter. Chemicals had been used in Egypt many years for the purification of the water of the river Nile, and the suggestion was taken up by some

of the filter companies, and the process developed into the rapid method of filtration as we now know it. The ordinary chemical used is sulphate of aluminum. This substance is first dissolved and the solution introduced into the water to be purified and thoroughly mixed with it. That produces a precipitate which entangles the impurities and carries them to the bottom; a portion of the precipitate in the form of fleecy masses is deposited on and through the sand bed and then entangles other passing impurities as does the mat in the other process. The water is passed rapidly through the sand and the impurities will be washed through it if the bed is run too long, so it must be shut down and washed from time to time. This washing takes place from once in six hours to once in forty-eight hours, dependent upon the character of the water, and is performed by pumping water into the under drains and at the same time stirring up the bed with rakes or compressed air, thus floating the collected impurities to the surface, whence they are carried away to a sewer. Early plants of this type which were put in were not in all cases successful. There were many of those plants that are claimed to have been successful which really were not so. The filter companies naturally did not wish to build a different machine every time they built one, and consequently they did not make any special study of the water with which they dealt. The treatment of water is not widely different from the treatment of disease. For success you must find out what sort of a treatment a particular water must have. As a result a great many of their plants were failures, and very few, if any, were unqualified successes. Along in the 90's, however, Providence took up water purification, and undertook a series of experiments upon rapid filters. The results showed greater possibilities than had previously been anticipated, and these experiments were followed by others at Louisville, Cincinnati, and Pittsburgh, and since then at St. Louis. There have been constructed within the past two or three years some very successful plants operated on this system. The first was that of the East Jersey Water Company at Little Falls, N. J., having a present capacity of about 34,000,000 gallons per day, designed by Mr. George W. Fuller. The next one of importance was that at Ithaca, and that was followed by one at Watertown, both by Mr. Allen Hazen; the efficiencies being in all three about the same as for slow sand; so that we may say that this method has proved its right to stand with the older one. The difference is that with a slow sand filter the longer you let it alone the better work it will do, but with the mechanical filter the operator has to be on deck all the time. He must see to it that all the water receives the proper dose of medicine. With the rapid filter the water must always be clear to be safe; if it is at all turbid when it comes from the filter, that is absolute proof that the purification is imperfect. So that where you have a water that can be handled with slow sand filtration it is safer. You are less likely to have a slip on account of the failure of an attendant. Where you have to make use of the rapid filter it will give good results if you put it into competent hands.

This has described what we can do with a bad water supply if we have to. I do not advise purifying a bad water, it is better to get a pure water to start with, but if we cannot get such an one naturally, we do not give it up.

University of Michigan.

DISCUSSION.

DR. LANE:

The primary use of a water supply is not domestic use. The primary use of the water supply is fire protection. The first reason for putting in city water is fire protection. The amount of water used is something like 100 gallons per day per person. Of that only about one-quarter is drunk. It might be that it would be cheaper and would pay to make each individual boil his water than to try to make the water safe for drinking use if it were otherwise desirable. There is another thing to be considered; that is the use for laundries and boilers which need soft water. It may be desirable to use artesian wells.

PROF. CAMPBELL:

With many large factories now it is a very important problem as to water softening, and nearly all the large railroads are introducing water softening systems.

MR. LEVERETT:

I think Dr. Vaughan might throw some light on that St. Louis matter.

DR. VAUGHAN:

Prof. Williams was employed by the State of Missouri and I was employed by the State of Illinois. I differ from Prof. Williams on one point. I do not think there was any increase in typhoid fever in St. Louis. St. Louis has kept excellent records of typhoid fever. They have very complete records and there is scarcely a city in the union which has such records. Investigations which followed the Spanish War in 1898 showed that what was thought to be Malaria was typhoid fever. St. Louis, after that reported all deaths as due to typhoid fever, where formerly some were called malaria.

PROF. WILLIAMS:

I would say that it was extremely fortunate that they began this change of recording cases just ten weeks after the opening of the canal; if they had begun six weeks after or twelve weeks after the effect would have been different, but as they began just ten weeks after the canal was opened it saved Illinois' case.

IDEALS CONCERNING MUNICIPAL WATER SUPPLIES.

ISRAEL C. RUSSELL.

The requisite conditions in reference to the water supply of a city may be tersely stated by saying that it should be abundant and wholesome. The first of these postulates must be understood as being sufficiently elastic to meet a wide range of conditions, but the second is rigid, as the same high standard of purity should be maintained in the case of all water used for domestic purposes.

In reference to the amount of water to be supplied to a city, two leading considerations need to be kept in mind; one is the quantity of water desirable for domestic uses, and the other the necessary provision that should be made for fire protection.

Water for Domestic Uses: The quantity of water that should be provided for the domestic use of the inhabitants of a city, has been considered by numerous municipalities, and the conclusion reached although varying between wide limits, is expressed perhaps with sufficient accuracy in a report on the water supply of Philadelphia, published in 1899. In preparing this report a large amount of evidence was carefully considered, and the conclusion reached that the minimum amount should be 150 gallons (681 liters) per individual per day. Although this at first glance may seem an excessive quantity, yet it is to be borne in mind that domestic use of water in a city cannot be strictly separated from its commercial use, and for fire protection. With these considerations in mind the estimate given above may be assumed as a basis for estimating the volume of water required for a municipal supply. This volume should be continuously available for the use of every inhabitant of a city, and to meet this end a suitable distribution system must of necessity be provided.

Water for Fire Protection: In making plans for the protection of a city against fire, the conditions to be considered vary much more widely than they do when domestic use is alone considered. Cities in which tall buildings exist or are likely to be built, of necessity require greater water pressure, than when the buildings are low. An adjustment in these and analogous respects can be provided by augmenting the hydrant pressure by means of fire engines and of private pumps, but where the pressure in water mains is the chief reliance, a desirable standard as experience seems to dictate, is that a sufficient volume of water should be available to maintain at least four fire streams with a diameter of one inch at the hose nozzle, for five hours, through hose pipes fifty feet long, with a pressure of at least ninety pounds to the square inch. Here again the distribution system needs to be properly adjusted to a variety of conditions; and as an ideal standard each building in the city is within reach of at least four efficient fire streams.

WHOLESOME WATER.

By wholesome water is meant water that when drunk by man is in every way conducive and in no way detrimental to the health of an individual using it. To meet these requirements it should be free from disease producing germs, and of such chemical composition that no deleterious effects to the health of an individual would result from its continuous use for a series of years. In addition to these requirements, water in order to be adjudged wholesome, should be clear, free from unpleasant odors and disagreeable taste and in no way contaminated with sewage or other substances which might lead to prejudice or repugnance against its free use for domestic purposes.

To claim that water for domestic use should be free from germs of all kinds, is beyond the ideal, since as we are assured by bacteriologists, certain bacteria and protozoa, are not only harmless to man, but beneficial, for the reason that they are the natural enemies or competitors of dangerous species. In nature as it appears, the only germ free water that can be obtained for municipal purposes, is such as is supplied by deep wells and by certain classes of springs. Other considerations bearing on the use of such waters will be noted below.

Chemically pure water is of still greater rarity in nature than germ free water, and it is safe to say that every drop of water met with on the earth, contains mineral matter in solution. Chemically pure water, however, is no more to be desired for domestic use than germ-free water, as certain mineral substances in solution when not in too great abundance are not only desirable but requisite. Ordinary surface water, such as forms fresh-water streams and lakes, has a highly complex chemical composition, and in fact nearly all known elements could as it appears be detected in it. The volume of the invisible freight which streams carry, is surprising to persons who have not given it careful consideration. A considerable number of analyses of river water compiled by Sir John Murray, shows that the larger rivers of the earth contain on an average about 762,587 tons of dissolved mineral matter to the cubic mile of water. An average based on analyses of a large number of the river waters of North America, gives for total solids in solution, 150.44 parts per million, and for calcium carbonate, the most abundant substance in solution in ordinary fresh water, 56.416 parts per million by weight. These figures may be taken as representing about the average chemical composition of the waters to which the people of this continent have become accustomed. In other words, an adjustant between human needs and the nature of the water supply has been reached, which furnishes a desirable standard for comparison. An ideal water for municipal purposes as may be justly claimed from the average conditions met with in America, should not contain more of total solids, or of calcium carbonate in solution, than is indicated by the figures just quoted. This standard of purity, however, is more rigid than has been adopted in Europe, where the streams in general are considerably less pure than in North America. At an International Sanitary Congress held in Brussels in 1852, and since reconsidered and readopted at several subsequent conferences of sanitary experts, it was declared that water containing more than thirty-five grains per (imperial) gallon, or 500 parts per million by weight, is not wholesome;

and that there "should not be more than one grain of organic matter to the gallon." The consensus of opinion arrived at during the discussions referred to, was that calcium carbonate in excess of 170 parts per million, is detrimental to health. A standard of purity based on the average chemical composition of the rivers and lakes of this country, would no doubt demand a greater degree of purity than has been decided as sufficient to insure health in Europe, but until such a standard is framed by American experts in hygiene, municipalities will be constrained to assume that water which is good enough for the people of Europe, will suffice for the people of America. It seems but reasonable to assert, however, that water which makes a near approach to the danger line stated above, should be regarded with suspicion, and not used for drinking unless no better supply can be obtained.

Not only is the standard of chemical purity just indicated, desirable in reference to the health of communities, but it has an important bearing on the commercial uses of water. The more nearly chemically pure a water is, the less the expense incident to the formation of "scale" in steam boilers, and the less the cost of soap used in connection with it. The maximum limit of mineral matter in solution, adopted by the United States Geological Survey, in reference to its use for generation of steam, is 140 parts per million. Each of the items just mentioned as well as several others in reference to the chemistry of water, becomes of great importance when the water supply of a city is considered.

There is an inferior as well as a superior limit, however, to the proportion of mineral matter which water should contain in solution in order to be wholesome, and certain water as that supplied directly by rain for example, may contain too small a percentage of mineral substances to be thoroughly desirable. The lower limit adopted at the Brussels Congress and subsequently confirmed at later conferences of a similar nature, is 130 parts per million for total mineral matter, and for calcium carbonate, sixteen parts per million. The most desirable proportions among the several mineral substances usually occuring in solution, has also been at least approximately determined, but will not be considered at this time.

In reference to the "one grain of organic matter to a gallon," stated by the Brussels Congress to be permissible in wholesome water, it is evident that uncertainties might arise as to the true meaning intended. Disease producing germs are evidently not to be included within this limit. A clearer and as is evident a more reasonable conclusion in this connection, has been placed on record in an essay on the sanitary chemistry of waters, by Professor C. F. Chandler, for a term of years President of the Board of Health of New York, which reads as follows: "Organic matter of a purely vegetable origin, such as occurs to the extent of one, two, or three grains per gallon, in country springs and wells, or in ponds and rivers, even when it contributes a tint of yellow to the water, is entirely harmless and unobjectionable. The nitrates, nitrites and ammonia salts found in wells in densely peopled towns are themselves harmless, but their presence proves the contamination of the water with the products of decomposition of animal refuse, and should always be viewed in the light of a warning of the presence of im-

pending danger." In this same essay, in discussing the dangers arising from animal excreta, the important statement is made that decomposing animal substances are highly dangerous, even when in minute quantities; and that filtered sewage though clear and transparent may carry with it the germs of disease.

In addition to freedom from disease-producing organisms and to the standard just stated in reference to chemical composition, wholesome water should be clear or essentially free from all matter in suspension, and as noted above, not be open to the suspicion that it contains sewage or other material which may lead to prejudice against its use for drinking purposes. This last standard which it seems desirable to establish, may perhaps, by some persons, be considered as ultra-ideal, when practical considerations are taken into account, but it is certainly reasonable to demand that drinking water should not contain sewage or other suspicious ingredients, even though the microscope fails to reveal the presence of disease-producing germs.

In order to establish an ideal towards which persons in charge of the water supplies of cities may strive to approximate, it should also be born in mind that temperature has an important bearing on the wholesomeness of water used for drinking. While the habits of individuals in this connection are not under the control of municipalities, it is obvious that if the water supplied to a city is of such a temperature as to meet reasonable desires, the use of iced water particularly during hot weather would be greatly decreased and a danger to the general health of a community thus lessened. In this connection the desirability of providing reservoirs with covers, to be considered below, is worthy of consideration.

SOURCES OF MUNICIPAL WATER SUPPLY.

The sources of water supply available for the use of cities may be classified as (1) rain water, (2) shallow wells and cold springs,* (3) deep wells and warm or hot springs, and (4) streams and lakes.

Rain Water: In certain instances the only available supply of water for domestic use is rain. So far as I am aware no municipality in the United States endeavors to store rain water for public use, but individuals construct cisterns, etc., for themselves. The amount of water an individual provides for his own use or for the use of a household, etc., is a private matter, but the healthfulness of the supply is of public concern. Intelligent supervision of cisterns when used as a means of domestic water supply, thus becomes as legitimately a matter of municipal supervision as the safeguarding of wells when utilized in a similar way.

Rain, in falling through the air, washes from it dust particles including living organisms, and in thickly settled regions, or whenever disease-producing germs are disseminated through the air, may reach the earth in an unwholesome condition. Its liability to contamination is enhanced as it flows over roofs, etc., and on entering a cistern, the

*The classification of springs uses here is arbitrary, but suggestive in reference to the domestic uses of such water supplies; by cold spring is meant one not sensibly influenced by the earth's internal heat, and in general conformable in temperature, to the mean annual temperature of the surface at the locality where it is located, and in the case of warm and hot springs the reverse of these conditions obtains

seeds of life thus gathered—for the very reason that they may not be in great abundance or variety, thus allowing such as are present favorable conditions for development—are likely to increase in numbers if the conditions in reference to temperature and light are favorable. To prevent farther contamination and especially to exclude mosquitoes from cisterns, they should be properly covered. Rain water, however, as usually gathered, contains a relatively high percentage of inorganic matter either in suspension or in solution, which is liable to undergo decomposition, and render it foul and unhealthy to man. In order to counteract this tendency as far as practicable, adequate ventilation, suitable overflow pipes, and frequent cleansing of cisterns should be provided for. In reference to the use of rain water for domestic purposes the fact should be borne in mind, as stated above, that it is deficient in the mineral matter in solution to an extent which for continuous use for drinking, renders it unwholesome.

When all precautions have been taken to preserve the purity of rain water, when desired for domestic use, it is safe to assume that it should not be taken internally by man, unless well boiled or thoroughly filtered.

For use as a means of fire protection, rain water is obviously as serviceable as water from any other source, and for use in generating steam it is no doubt superior to any other water that can be obtained, for the reason that its content of mineral matter in solution is far below that of average streams and springs. In regions where water is scarce and even in humid regions where the streams and springs are abnormally high in mineral matter in solution, the construction of gathering grounds for rain water in excess of that supplied by roofs, might be advisable and practicable, in order to obtain water for fire protection and for generating steam.

Shallow Wells: In regions where the surface level of soil saturation or the water table, is within approximately fifty feet or less of the surface, the obtaining water by means of ordinary dug wells is practicable, and such wells may be utilized as a source of municipal water supply. The ideal conditions in this connection are; sufficient volume of water especially during dry seasons, to be obtained economically, and also that the water shall be wholesome.

Shallow wells, however, especially if situated in the vicinity of thickly inhabited regions, are always to be viewed with suspicion; and in general it is safe to say, such sources of supply should not be utilized for municipal purposes except as a last resort. In case it is necessary to use them every possible care needs to be taken to decrease the dangers of contamination, and the water properly filtered before it should be considered suitable for domestic use. The practice sometimes indulged in, of depending on natural filtration during the process of percolating into a shallow well, is not wise, as the condition and nature of the so-called filter is seldom if ever thoroughly known.

The chemical nature of the water supplied by shallow wells and cold or hill-side springs, also demands attention. In many regions where such sources of water supply are utilized, the superficial blanket of rock waste is highly sandy and the underlying rocks contain but a small percentage of easily soluble material, and the water is of a com-

paratively high degree of chemical purity. If however, the soil and subsoil contain limestone or other easily soluble rock debris, as is the case generally in the moraine covered portions of Michigan for example, the water after percolating through it, is apt to be too highly charged with material in solution to be thoroughly wholesome.

Deep Wells: The deeper a well is sunk in the earth the less the chances of the water supplied by it becoming contaminated with living organisms, but the greater the opportunity for it to disolve mineral matter. These propositions are based of course, on the assumption that water enters the well at or near its bottom.

Deep wells and springs rising from a deep source, furnish practically the only source of water supply for cities which are free from danger of contamination by living organisms. It being understood in this connection that proper care has been exercised in reference to the introduction of organisms into the well during the process of drilling, as on well points for example, and that the water is properly cared for after it reaches the surface. When these precautions are taken, the water of deep wells furnishes the best of all supplies for city use, providing the percent of mineral matter in solution is within certain limits in reference to its nature and quantity.

Having obtained an adequate supply of water from a deep source for municipal purposes, however, it is essential that its freedom from organic contamination should be maintained. In this connection a note of warning needs to be sounded, since in many instances, germ-free water is stored in open reservoirs before reaching the consumer, and thus exposed to the danger of becoming contaminated from the air. This source of danger is especially marked in the case of the class of waters under consideration, since the absence or scarcity of life in them, including forms not deleterious to the health of man, but which as is stated by bacteriologists, are in certain instances the enemies of dangerous species, or at least enter into competition with them, permits of the rapid development of noxious forms in case they do gain admission.

When water from deep wells or pure springs is utilized by municipalities, the conditions under which it existed before coming to the surface, needs to be maintained so far as possible. If the water is stored in reservoirs, such receptacle should be roofed, and during the passage of the water through water pipes, etc., man holes and other similar openings should be tightly closed. Objections arise, however, in reference to the use of covered reservoirs in addition to the expense they involve. In many instances the water delivered by deep wells and by springs, is of such chemical composition as to make it desirable to thoroughly aerate it. In many instances such waters contain gases which it is desirable to allow to escape, or are impregnated with mineral matter such as iron oxide and calcium carbonate, which if exposed to the air will in a measure be precipitated. Then too, water from a deep source is in general deficient in dissolved air, and as people are accustomed to drink thoroughly aerated water, its taste is insipid. For these reasons thorough exposure to the air of water derived from a deep source is in many instances desirable.

How to keep water derived from a deep source from becoming con-

taminated with objectionable forms of life, and at the same time secure the desired amount of aeration, is a somewhat difficult problem. The details in this connection must of necessity be studied for each special locality, but in general it is safe to say that such water should be to fall in a spray within a roofed reservoir to which only filtered air is admitted and light excluded. Such a provision carries with it also, a lowering of the percentage of loss on account of evaporation, and prevents a reservoir from becoming a breeding place for mosquitoes, as well as eliminating the danger of its becoming foul on account of the growth and decay of algae.

Streams and Lakes: Lakes are in general expansions of streams, but in some instances and particularly in Michigan, they originate in other ways and are without surface outlets. Examples of enclosed lakes are abundant in many regions where the surface of the land is composed of glacial drift, and occupy depressions which extend below the water table. Water enters them wholly or in part by percolation through the material forming the bordering land and their surface levels are dependent on the horizon of the water table. For this reason they are similar to shallow wells and are exposed to similar danger of contamination.

When streams or small lakes are utilized for municipal water supplies, two general plans for striving to insure freedom from organic contamination present themselves for consideration: one is to endeavor to prevent contamination of the supply and the other to guard against such contamination by filtering or by boiling the water. The most logical method is obviously to take advantage of both of these means. The sources of supply should be safeguarded so far as possible, and the water suitably filtered or boiled before being used for domestic purposes. The boiling of water is as it seems impracticable so far as the municipal care of the supply is concerned, and must be left to the individual.

If the region tributary to a surface water supply can be maintained in its primitive or natural condition, and men and domestic animals excluded, the water derived from it may under normal conditions be adjudged reasonably safe and filtration dispensed with. In a region which is inhabited and to a greater or less extent utilized for agricultural purposes, however, it is seldom possible to insure such a degree of freedom from danger of organic contamination, that the surface water supplied by it can be safely used for municipal purposes without filtration.

In the case of lakes or streams which are utilized for navigation, a special element of danger is introduced which demands serious consideration in case the water from such sources is used for domestic purposes. The passage of vessels over a water body as the Great Lakes for example, leads to the direct introduction into them of refuse of many kinds, including the most noxious of all, namely human excrement. In this connection it should be noted that vessels carry people from city to city, and that cities are centers of distribution for many diseases. This imminent source of danger does not seem to have been duly considered in the case of several of the cities of Michigan which derive their water supply from the Great Lakes.

In addition to the danger of contamination of lakes from vessels, they receive the surface wash from the land tributary to them and in numerous instances are also the receptacles for the sewage of cities, the refuse of factories, etc. In these several ways they are liable to become contaminated, the danger being most imminent in the vicinity of the localities where sewage is discharged into them and where vessels pass in large numbers. To be sure, the great volume of water present serves to dilute the contributions of sewage, and freedom of exposure to the air promotes oxidation, thus diminishing the danger to persons who drink the water, but as is well known, the water of even the Great Lakes has in several instances served to disseminate certain diseases. An important investigation in this connection, which so far as I have been able to learn has not been made, is in reference to the life histories and rate of increase or diminution of diseases producing germs after entering an open water body such as a large lake.

While the waters of lakes at a distance from the mouths of sewers and away from the tracks frequented by vessels, are among the very best of natural water supplies, Lake Superior, for example, being probably the purest, both chemically and bacteriologically, of any considerable water body on the earth, yet it is self evident that a city cannot discharge its sewage into a lake and take its water supply from it at a nearby locality or from the vicinity of the routes frequented by vessels, without serious danger. While the water supply of an individual city, whether taken from a lake or from some other source, presents concrete problems for study and should be specially considered, it is safe to say as a general proposition, that even if the greatest care is taken in locating intakes with reference to the places where sewers discharge and with regard also to the routes followed by vessels, filtration is still desirable. A common sense reason for establishing such a safeguard, is that it is possible to exercise continuous watchfulness when a filtration plant is used, while it is impracticable to predict when contamination will occur in case such a precaution is not taken.

In connection with the use of the water of streams and lakes for municipal purposes, the liability of the supply becoming turbid or even muddy during heavy rains and in the case of lakes, on account of the action of shore currents generated by strong winds, have also to be duly considered. To counteract such undesirable conditions, settling basins for the water used should be provided, or filtration resorted to. In certain instances, as is well known, both of these methods have to be employed.

CONCLUSIONS.

Even a brief review, such as is here attempted, of the ideals which municipalities should strive to attain, renders certain conclusions self evident. These, as it appears, may be stated as axioms from which there is no logical appeal. They are:

First. When water derived from a deep source in the earth is utilized for domestic purposes, every possible precaution should be taken to prevent its becoming contaminated by disease-producing germs, owing to exposure to the air.

Second. Every care should be taken to prevent the contamination

of surface waters and shallow wells, but that even when all practicable means to arrive at this end have been employed, such sources of supply are to be viewed with suspicion, and the health of communities still farther guarded in many instances by filtering the water.

In order to reduce the danger of surface water becoming unwholesome, every household, every community, every city, every factory, every slaughter house, etc., should be required to destroy or render harmless and unobjectionable its own refuse, before it is permitted to enter streams or other surface water bodies, and also before it is distributed in such a manner as to be dangerous or annoying through the action of the wind or in other ways. The aim in view in this connection, is to abate the menaces to life and health, and to comfort and happiness, incident to the growth of communities, and reap the benefits of civilization without augmenting the evils that flesh is heir to.

The subjects touched on in this brief essay, have a bearing on and are ultimately to a grave extent dependent on a still larger problem incident to the spread of civilization, namely the conservation of the volume and regularly of flow of streams, by sane forestry and agricultural methods.

University of Michigan.

ISOLATION AS A PREVENTIVE MEASURE.

GUY L. KIEFER.

The three principal general methods in vogue at present for the restriction of communicable diseases are immunization, isolation and disinfection. Under the head of immunization may be classed vaccination for the prevention of smallpox and antitoxin as a prophylactic measure against diphtheria. Isolation and disinfection are applicable to a great number of diseases. Even before preventive medicine became a definite science and before the establishment of boards of health for the purpose of executing the laws of hygiene, it was customary to some extent to separate those suffering with a contagious disease from those not infected. Even before the days of Jenner people avoided smallpox patients whenever they knew of the existence of the disease. But it is only of recent years that isolation—the separation of the sick from the well and the well from the sick—has become a police regulation. In order that boards of health might be enabled to enforce isolation, laws have been enacted by various states requiring physicians, parents and householders to report the existence of cases of communicable diseases to the local health authorities. These laws are similar in different states, but differ as to the diseases that are required to be reported and which, for the sake of convenience, I will designate as "notifiable diseases." In Michigan the law reads as follows:

Sec. 43. "Whenever any householder, hotelkeeper, keeper of a boarding house, or tenant, shall know, or shall be informed by a physician, or shall have reason to believe that any person in his family, hotel, boarding house or premises, is taken sick with smallpox, cholera, diphtheria, scarlet fever, or any other disease dangerous to the public health, he shall immediately give notice, in writing, thereof to the health officer of the township, city or village in which he resides."

Sec. 44. "Whenever any physician shall know that any person whom he is called to visit, or who is brought to him for examination, is infected with smallpox, cholera, diphtheria, scarlet fever, or any other disease dangerous to the public health, he shall immediately give notice thereof to the health officer of the township, city or village, in which the sick person may be; and to the householder, hotelkeeper, keeper of boarding house, or tenant within whose house or rooms the sick person may be."

It will be noticed that the law specifies "smallpox, cholera, diphtheria and scarlet fever," and then goes on to say "or any other disease dangerous to the public health." It would be better if each disease that is dangerous to the public health were enumerated so that there could be no chance for an argument between physician and public health authority. It is due to this lameness in the law that not nearly all diseases which are really communicable and dangerous to the public health are

reported, and it is certainly necessary first to have a case reported before steps can be taken for its isolation. Accordingly the success of isolation as a preventive measure depends upon the prompt notification of the cases to the local health officer and this notification in turn depends upon a number of factors, as follows:

1. The severity of the disease.
2. The duration of the disease.
3. The difficulty of diagnosis.
4. The duration of the infective period.

In cases of a severe disease or one which is considered severe by those outside of the medical profession, notification is usually prompt. As an example of this class, smallpox may be mentioned. Whenever a person is suspected of having smallpox, the health officer can not act too promptly. Not only the householder reports the case, but even the neighbors make it their business to aid in the notification; but when on the other hand measles is the disease in question, no one seems to care. The feeling prevails that measles is a mild disease and every child ough to have it, and so in the case of measles, isolation as a preventive measure fails almost entirely, and yet measles claims many more deaths annually than does that much-dreaded disease smallpox. The second factor, duration of disease, works against isolation in much the same way. When people know that their quarantine is to be comparatively short they are willing to be locked up, but the longer the quarantine the more anxious are they to avoid it; as a consequence diphtheria is more liable to be reported than scarlet fever and the latter disease will be reported when one of longer duration would be suppressed.

The difficulty of diagnosis is an important factor to the success or failure of isolation. Typical cases of diphtheria, scarlet fever and smallpox are easily recognized and are for the most part reported, but the milder cases escape detection and consequently isolation. Mild diphtheria is called tonsilitis, scarlet fever is often designated as stomach rash, erythema or even urticaria, and is allowed to run at large, whereas the cases of mild smallpox are diagnosed as cuban itch, impetigo contagiosa, chicken-pox and what not.

The fourth factor that has a bearing on isolation, the duration of the infective period of the disease, is of importance in those diseases that are communicable early in their course, even before a definite diagnosis can be made. For example, measles is infective before the appearance of the eruption and mumps before the parotiditis has appeared, and consequently even if these diseases are notifiable some exposures will take place before the cases can be isolated, whereas in the case of smallpox there is little chance for infection before the appearance of the eruption.

Taking all these factors into consideration, what can be done to make isolation effective? First of all, every disease that is communicable and dangerous to the public health should be mentioned in the law, making the disease notifiable. Secondly, all *suspicious* cases should be reported so that the health officer may see them and protect the public if, in his opinion, the disease is dangerous. Doubtful cases of diphtheria should be decided by a bacteriological examination of a throat culture.

In order to reach the very mild cases that have probably not been under the care of a physician, there should be a careful systematic medical inspection of schools in each community. A competent medical examiner should visit each school daily and personally examine all children who have been absent or who appear suspicious of being ill. In this way many otherwise undetected cases are discovered and may be isolated. In Detroit we are finding cases of diphtheria and scarlet fever in the schools continuously and they are, of course, promptly excluded and isolated. During the month of February fifty cases of whooping-cough were excluded from the Detroit public schools, and to this extent at least the danger of transmitting the disease was removed.

By these various means it will be possible for us to get track of cases of communicable diseases. And now comes the question, how shall they be isolated? Is it safe practice to isolate cases of scarlet fever, diphtheria and smallpox in a private house? If so, should a general quarantine of all inmates be established or can the patient be isolated in one room or a suite of rooms and the rest of the family be given free ingress and egress? The last question should be answered in the negative. It may be theoretically possible to prevent the spread of these diseases by separating the patient off in a room, by handing dishes and food in at the door and having whatever comes out carefully disinfected before it does leave the sick room, but practically such isolation is useless, and possibly worse than useless, because it gives a feeling of security which is always dangerous when it is not real. As to the question of establishing a general quarantine over the entire household in which the case is found. This may be done, but it would involve an unnecessary exposure to disease of all the other members of the family and would necessitate an unwarranted expense to the community. In the case of poor families it becomes the duty of the State to feed and provide for them when they are under quarantine, and more than that, in order to insure an effective quarantine, guards should be placed at the front and rear of the infected house day and night, involving an expense of approximately twelve dollars per day per house. What then is the proper way to isolate and by means of isolation to prevent the spread of disease and protect the public health? The first requisite in every community for carrying into effect this general prophylactic measure is a first-class, modern, well appointed hospital for the reception and treatment of communicable disease of various kinds. Such a hospital should be built on the pavilion style, having separate buildings for the different diseases, and should be under the control and supervision of the local board of health. If the proper kind of building were at hand, nearly every one would be willing to make use of it when the occasion demanded. All cases of contagious disease could then be removed promptly to the hospital, the house from which they were taken and its contents disinfected and the exposures kept under surveillance for a length of time equal to the period of incubation of the given disease. Any additional case that might develop would then be detected immediately and in turn removed to the hospital. At that institution the isolation would be absolute and it could be controlled. No one would be allowed to enter or leave the hospital unless they carefully obeyed all rules and regulations of the board of health as to pro-

tection of clothing on entering and disinfection on leaving. In this way even the danger of the spread of the disease by the attending physician would be removed.

In conclusion I would say that isolation as a preventive measure is invaluable, but it must be a real and not an imaginary isolation. To insure such an isolation there are three principal requirements:

First, all diseases that are to be isolated should be specifically mentioned in the law and thus made notifiable.

Second, there should be a daily medical inspection of school children for the purpose of detecting otherwise unrecognized cases of disease.

Third, there must be a proper hospital for the reception and treatment of communicable diseases under the supervision and control of the local board of health.

Detroit, Michigan.

MEAT INSPECTION AS AN AID TO THE PREVENTION OF DISEASE.

E. H. HAYWARD.

Since the diet of mankind, especially in this country, consists largely of the flesh of animals, fish and birds, it is apparent that a careful inspection of the same should be maintained, to the end that this flesh may be furnished for edible purposes in a sound and healthy condition.

There have been many cases of sickness, often in an epidemic form, which are directly traceable to the ingestion of diseased meat. As a hygienic measure and for the purpose of protecting the public from such outbreaks, our legislature has enacted laws governing the sale of meat and prohibiting the marketing for food of such as may be detrimental to the health of the community.

The inspection of meat is as a rule under the supervision of the local sanitary authorities, the board of health, and forms a department of its own, apart from other food inspections. The duties of a meat inspector are:

(1) To see that suitable animals are selected for slaughter.
(2) To see that the animals are slaughtered in a proper manner.
(3) To see to the sanitary arrangements of the slaughter house.

There are but few cities in the country which maintain public abbatoirs, and as a consequence the work of the meat inspector can not be complete. It is impossible with the staff of men employed in any one city to visit and control the slaughtering and sale of meat when it is distributed all over a large and populous municipality. The ideal condition of one large central abbatoir with a corps of efficient inspectors exists only in the large cities of Europe, Berlin, Paris, Munich, etc.

The slaughter and disposal of the meat of animals has been subject to laws and regulations for centuries. Since the time of Moses down to the present century various nations have maintained a system of meat inspection of more or less efficiency. The principal objects of meat inspection are to exclude meat which is unfit for food on account of:

(1) The presence of diseases dangerous to man.
(2) The presence of decomposition.

The living animal should be inspected within twenty-four hours of killing, and the points to observe are that the animal is well grown, properly nourished and has the appearance of health. Cattle should be three to eight years of age, this may be determined by the teeth. The age of a pig can not be told after three years. The flesh should be firm and elastic, the skin supple. Health is manifested by ease of movement, a bright eye, a red and moist nasal mucosa and regular and easy respiration.

The color of normal meat varies from white in some fish to a dark

purple, as in horse flesh. Abnormal coloration may be due to melanosis, a black pigmentation, white flesh due to anaemia and anasarca, yellow flesh due to certain foods or the absorption of bile, a dark purple color due to acute fever, rinder pest, or tuberculosis, this color may also be due to insufficient bleeding after death, and a green or violet color due to decomposition.

The principal diseases which should be watched for by the inspector are:

In cattle—Pleuro-pneumonia, foot and mouth disease, anthrax, typhus contagiosus, actinomycosis, tuberculosis and Texas fever. In addition sheep should be inspected for variola ovina, erysipelas, phthisis, fluke disease and gid.

Hogs must be carefully watched for anthrax, hog cholera, measles and trichiniasis.

It may not be out of place to mention briefly the symptoms of some of these diseases. *Epidemic pleuro-pneumonia* is an acute communicable disease affecting the lungs of cattle and is due to a specific organism. The incubation period is from one to two months, the first symptoms is cough, followed by fever and horripilation, the breathing meanwhile becomes labored and the expired air is very fetid, the pulse is rapid and prostration marked, finally the animal dies from exhaustion. Post-mortem, the lungs are gangrenous and full of abscesses, the pleura is inflamed and adherent, the alimentary tract may also be affected.

Foot and mouth disease is very rare in this country. It is evidenced by a vesicular eruption on the mucus membrane of the mouth and an elevation of temperature, the animal stands with its head down and a profuse discharge of saliva issuing from its mouth. The disease is highly contagious.

Anthrax is found in cattle, sheep and pigs. It is due to a specific infection with the anthrax bacillus. The incubation period is from one to four days. The disease occurs in one of three forms, the acute, subacute and exanthematous. In the acute form the animal may apparently be perfectly healthy, fall in a convulsion and die. The subacute form is evidenced by anorexia, inhibition of the secretions, fever and tremor. The pulse is rapid and the breathing labored, diarrhoea and exhaustion follow. In the exanthematous form we have pustules and rashes occurring. Post-mortem, the lungs are congested and the spleen, pericardium and serous membranes are covered with ecchymoses. The spleen, kidneys and liver are congested, enlarged and friable. The specific organism may be obtained in pure culture from these organs or from the blood.

Typhus contagiosum is an epidemic communicable disease favored by crowding and uncleanliness. From the onset the animal is listless, dull and stupid, intense thirst with loss of appetite and rumination occurs, the secretions are arrested and in some cases the animal becomes uncontrollable. The tongue and the buccal mucosa are inflamed and livid streaks appear which rapidly ulcerate. Later on in the disease the subcutaneous areolar tissue becomes emphysematous and the animal dies from toxaemia.

Actinomycosis is due to an infection by the ray fungus; this condition is also known as lump jaw or wooden tongue. The organism is

usually introduced through a laceration of the oral mucosa by a spear of hay or grain. The disease is characterized by the formation of nodules which break down and discharge through sinuses, these sinuses may heal to break out again in another place. If the jaw alone is affected the course of the disease is slow, the animal becoming very emaciated through inability to masticate. When metastases occur in the liver and other internal organs the functions are rapidly impaired and the symptoms are augmented. Death finally occurs. The specific organism may be found in the pus in the form of small yellow granules about the size of a pin-head which, under the microscope, show the characteristic form of the ray fungus.

Tuberculosis. The causative factor in this the most common condition of diseased meat is the tubercle bacillus. The disease is communicable and evidences definite and characteristic lesions. The order of frequency of primary infection is:

(1) The lymphatic system.
(2) The pleura and peritoneum.
(3) The lungs.
(4) The liver, kidneys and brain.

The udder of cows is frequently affected and many cases of simple mastitis are really tuberculosis. The site of the primary lesion depends, of course, on the avenue of infection.

If the serous membranes become infected they are covered with tubercles which coalesce, forming large nodules; this condition is known as "the grapes" or "angle berries," and in Germany as pearl disease or Perl sucht.

The course and symptoms of the disease depend on (1) as to whether the animal is predisposed, (2) the site of the disease and the organs involved, (3) the occurrence of secondary infection.

When the lung is affected the first symptom is a rough, weak cough, the respiration becoming weak and embarrassed. A continued fever with a marked diurnal exacerbation is also characteristic. If the udder is affected tubercle bacilli will be found in the milk, and even when no lesion can be demonstrated in these glands their presence in the milk has been detected. The use of tuberculin has done much to assist in the diagnosis of this condition in the living animal, and it should be employed in all doubtful cases, as it is harmless to nontubercular animals.

Glanders is a highly infectious disease, communicable to all animals with the exception of cattle and to the human. It may run an acute or chronic course and is most common in horses.

Variola Ovina, or smallpox, occurs in sheep and is exceedingly infectious and communicable to the human. It presents the same lesions and symptoms in the animal as it does in man.

Phthisis in sheep is due to an infection of the lung by the parasite strongylus filaria. The disease produces great emaciation and is not transmitted to the human.

Fluke disease affects cattle sheep and horses and is due to an infection by the distoma, the embryos of which are taken in with the drinking water which becomes contaminated by fecal matter. As the disease occurs in the human, infection taking place through the same source, all water used for drinking purposes should be carefully guarded from contamination.

Gid is a hydatid disease of the brain or cord in sheep, due to an infection by the coenurus cerebralis the embryonic form of the taenia coenurus of the dog.

Measles is caused by the presence of cysticercus cellulosæ in the muscles of the pig. This parasite is the cysticercoid form of the taenia solum or pork tape worm. Ingestion of raw or partially cooked meat infected with this parasite results in infection for the human, the embryo developing into the adult worm in the intestine. It was owing to the prevalence of this disease among hogs that pork was prohibited as a food stuff by Moses in early times.

The measles of cattle is due to infection by a similar organism, the cysticercus bovis, which is the embryonic form of the taenia saginata or beef worm, the most common tape worm of this country. Man is infected by consuming infected beef, either raw or partially cooked.

Trichiniasis, of which many epidemics occur in this country, is due to the ingestion of pork containing the embryos of the trichina spiralis. These embryos when encapsulated are capable of withstanding a temperature of 156 F. and a thorough cooking is necessary to destroy them.

Hydatid disease of cattle, sheep and hogs is due to infection by the ecchinococcus veterinorum. the proscolex stage of the tinea ecchinococcus of the dog. It is found most frequently in the lungs and liver of adult animals. Partaking of such meats, if not sufficiently cooked, frequently proves fatal.

The foregoing in brief summarises the more common diseases which may be transmitted from animal to man, either by contact with or consumption of the flesh of animals suffering from them. There is no doubt that much of such food finds its way into the market. This is not due to lack of vigilance on the part of the inspector but to insufficient organization of meat inspection in this country and the lack of appreciation of what calamities epidemics from this source may cause. Before an improvement of this condition may be hoped for such epidemics as recently occurred in Bay City must again be repeated before the public awakes to realize the importance of thorough meat inspection. The thorough cooking of meats in many cases protects the public from dangerous infections, but it is very questionable whether the toxins present in infected meat, and themselves capable of producing disease, are destroyed by this measure.

This vital question which affects the health particularly of people living in cities and who rely on others to distinguish good from bad can best be solved by the establishment of central abbatoirs where complete and efficient inspection, both before and after slaughter, can be made by men especially trained for that purpose.

Detroit, Michigan.

THE FLAGELLUM STAINING OF SPIROCHAETA OBERMEIRI.

CLOUGH TURRILL BURNETT.

To demonstrate the flagellum of Spirochaeta Obermeiri it is necessary to separate the spirochaetes from the blood containing them. The parasites are injected into the peritoneum of a white rat and appear in the blood two days later. This blood is drawn and allowed to stand, from eighteen to twenty-four hours. At the end of that time the blood cells will have settled to the bottom of the tube and above these there is a thin whitish layer of spirochaetes. Attempts were made to stain spreads made from this material, but this proved unsuccessful, as the blood plasma present masked the whips. To prevent this the plasma is drawn off with a sterile pipette, care being taken not to disturb the layer of spirochaetes, and its volume replaced by a normal salt solution. This tube is now sealed and centrifuged for twenty to thirty minutes and then is opened, the supernatant fluid removed and more salt solution put in, and after sealing again centrifuged. It may be necessary in some cases to repeat this operation three or four times, examinations being made each time the tube is opened. When in the hanging drop a clear field is obtained with only a few blood cells and many motile spirochaetes, spreads are made, dried in air and fixed five minutes in methyl alcohol. If agglutination is taking place there may appear on the surface of the layer of blood cells small whitish "islands" of spirochaetes. One of these islands can be picked up with a fine pipette and placed in suspension in a few drops of normal salt solution. If examination shows that there are still many motile spirochaetes present spreads may be made directly from this without centrifuging, for by this method there will not be enough blood plasma present to mask the whips.

The fixed cover-glasses are now treated with a hot mordant solution and then with a stain.

The mordant solution is that used by Duckwall slightly modified. Its composition is as follows:

Dry tannic acid—2 grams.
Distilled water—15 c. c.
Ferrous sulphate (cold water sol.)—4 c. c.
Fuchsin (saturated alcohol sol.)—1 c. c.

The tannin is added to the water and heated; then add the ferrous sulphate and last the fuchsin. Filter through a fine filter. There should be a thick heavy precipitate on the filter. The filtrate, which is the mordant solution, is a cloudy violet. This is good for not more than five hours and is best when fresh.

The stain is an anilin water fuchsin. To 100 c. c of a hot anilin water is added four to five grams of fuchsin. Stir well until dissolved, and filter. It has been found that the best results in flagella staining

are obtained when a weak alkali is added, so to this dye should be added 1 c. c. of a 1% NaOH solution. As both the mordant and the stain are used hot, these may be placed on a metal plate, one end of which is heated by a Bunsen burner, or they may be heated over a water bath.

The fixed cover-glass is now treated with the hot mordant. Before applying this it is best to cover the cover-glass with distilled water and heat to steaming, then put on the hot mordant. This prevents that precipitation which occurs when the hot mordant is placed on a cold cover-glass. Since in heating this mordant there is some precipitation, care should be taken not to boil it on the cover-glass. After treating with the steaming mordant solution for two minutes, wash under the tap until all deposit is removed. Again cover with distilled water and heat to steaming; then apply hot anilin water fuchsin for two and a half minutes, boiling gently at the end. Wash under tap, then with dil. alcohol and absolute alcohol until no more dye can be removed. Finally dip for one to two seconds in dilute HNO_3 (5 drops of C. P. acid to 10 c. c. water). If the cover-glass is transferred directly from alcohol to acid it should be removed as soon as possible and washed with water, as in this case we get the action of an acid alcohol which is a much stronger decolorizing agent. If the specimen is washed in water after being taken from alcohol, a longer time will be required in the acid. The specimen should be examined from time to time to make sure that decoloration is not carried too far. This procedure will show deeply-stained spirochates on an almost colorless background and may show some very faint terminal whips. If these are present they will probably be very hard to see, but by repeating the above procedure in its entirety, that is, by again treating with mordant and stain and decoloring carefully, a very fine terminal whip will be seen to stand out plainly. This whip is spiral in shape like the body of the cell, and by this method of staining appears to be about one-third as thick as the body of the spirochaete. It may be composed of from one to six turns; in one case a whip was found which was longer than the body of the cell. At the other end is a short stub which may mark the beginning of the formation of a flagellum. This blunt process does not appear in all forms which show a flagellum. Many organisms are found to be attached by their whips.

In my work thus far I have been unable to stain these whips without considerable precipitation, so that probably in many cases the whips have been masked by a heavy precipitate. This precipitate could be washed out with alcohol and acid, but in so doing the few whips present in these cases were decolorized. Also much care must be exercised in the complete removal of the blood plasma.

At present I am attempting to stain these whips by using this same mordant and dye, but at a constant temperature of 70°—77° C. The mordant and dye are made up at a temperature of 55°—60° C., so by this rise in temperature I am assured of complete solution of my dye and thus, I believe, reduce materially the precipitation.

This latter work has not progressed sufficiently far to warrant any report.

University of Michigan.

THE ASSOCIATION OF PSEUDOMONAS RADICICOLA WITH BACILLUS RAMOSUS.

WALTER G. SACKETT.

In preparing and developing liquid cultures of nodule forming bacteria in such quantity as is required when several hundred pounds of seed are to be inoculated, it not infrequently happens that during the growth of the germs, there is set up in the medium a fermentation not typical of Ps. radicicola, but one which is clearly an off fermentation.

Occasionally we have a vigorous gas production accompanied by an abundant formation of froth on top of the culture, giving every indication of a yeast at work, and an examination of such material will, in nearly every case, show a torula form to be present. More frequently, however, there develops a disagreeable, sour odor similar to putrefying water from a vase of flowers. Here, instead of the yeast we usually find a large, rather thick, motile bacillus, apparently of the B. ramosus type. Before going any farther, there are two questions which naturally suggest themselves; first, do these contaminations, for such they are, have any influence upon the growth of the nodule-forming bacteria, and if so is it to be regarded in the light of antagonism or mutualism, or in other words, is this association detrimental, neutral or beneficial to the growth of Ps. radicicola? The second query is this: if by exercising every precaution in our laboratory technique to keep out these contaminations, we still meet with them, how much greater is going to be the off fermentation when the rearing of these pure cultures is intrusted to the farmer whose knowledge of bacteriological methods is practically nil and whose facilities for sterilizing utensils and media are very limited.

Considerable has been said here and there bearing upon this question in a more or less general way and intimating that possibly the reason a culture failed to give the sought for inoculation of the roots of legumes was because other germs got into the cultures and in some way rendered it worthless. And then again, we can pick up literature in which are given directions for preparing these cultures and in nearly every instance the operator will be cautioned about keeping out dirt, for it is possible that other bacteria may exert a detrimental influence. But when we are pinned right down to the question, "Do you know that any of these germs are antagonistic towards Ps. radicicola?" we find that specific experimental data is sadly wanting. The importance of this question from a practical standpoint is so obvious that I can pass it by with mere mention for upon it may depend the success or failure in getting an efficient inoculation of a whole season's crop and with clover seed selling at from eight to ten dollars per bushel and alfalfa considerably higher, the farmer can not afford to waste many pounds of seed on a worthless culture.

With the hope of throwing some light upon this question from the experimental side, a series of investigations have been undertaken and are now in progress in our laboratory aimed primarily at the antagonism, if such it be, existant between different soil bacteria and the germ producing the nodules of the alfalfa plant. One of these experiments only will be reported upon here and that of a more or less preliminary nature.

The organisms selected for this first work were B. ramosus and Ps. radicicola, (alfalfa). A twenty-four hour bouillon culture of each germ was prepared and a known number of cells from each culture were introduced into one of two flasks of sterile salt solution. We then had a suspension of alfalfa germs containing a known number of cells in one flask and a similar suspension of B. ramosus in the other. One c. c. of the alfalfa suspension with its known bacterial content was then used to inoculate 99 c.c. of a nutrient sugar solution contained in a 200 c. c. Erlenmeyer flask; a second flask of sugar solution as above was inoculated with one c. c. of the B. ramosus suspension; into a third flask of the same medium was introduced one c. c. each of the alfalfa and B. ramosus suspensions. We had now one flask with the alfalfa alone, one with ramosus alone and the third containing both organisms. These were kept at a temperature of 28° C. for twenty-four hours, at the end of which time, quantitative dilution plates were made in a sugar agar and the relative counts determined later. Again after 48 hrs, 72 hrs., 96 hrs., five days and 6 days, dilution plates were made from the three flasks described above and their counts determined as given in the table below. Four different lots of cultures, prepared precisely as here described, have been worked with and the counts made for periods as previously given, the results of which will follow.

During all of our investigations the cultures in flasks have been kept as near 28° C. as possible, that being the optimum for alfalfa. Some difficulty was experienced at first with the B. ramosus spreading on the plates when kept at this high temperature and so in all subsequent work the plates have been allowed to develop at approximately 23°C.

This temperature has another advantage aside from eliminating spreaders for at 23° C. the B. ramosus colonies are plainly visible after 48 hrs., and can be counted, while the alfalfa colonies seldom appear before the fourth day. By this means it was a very simple matter to check the counts on the plate said to contain both organisms. Aside from this temperature relation, the colonies of each germ are so very characteristic that no difficulty was ever experienced in deciding which was which.

Tables showing colony counts on dilution plates.

SERIES I.

Name of organism.....	No. germs introduced.	No. germs per c. c. in 24 hrs.	No. germs per c. c. in 48 hrs.	No. germs per c. c. in 72 hrs.	No. germs per c. c. in 22 days.
B. ramosus.....	500	4,000,000	37,000,000	23,000,000	6,000,000
Ps. radicicola alfalfa.....	226	*	38,000,000	203,000,000	116,000,000
B. ramosus.....	500	86,000,000	70,000,000	37,000,000	28,000,000
+					
Ps. radicicola alfalfa.....	226	0	0	0	0

* Dilution too high.

SERIES II.

Name of organism.....	No. germs introduced.	No. germs per c.c c. in 24 hrs.	No. germs per c. c. in 48 hrs.	No. germs per c. c. in 72 hrs.	No. germs per c. c. in 6 days.
B. ramosus.....	5	42,000,000	10,000,000	21,000,000	10,000,000
Ps. radicicola alfalfa.....	199	7,600	6,000,000	330,000,000	700,000,00
B. ramosus.....	5	18,000,000	1,000,000	4,000,000	1,000,000
+					
Ps. radicicola alfalfa.....	199	0	0	0	0

SERIES III.

Name of organism.....	No. germs introduced.	No. germs per c. c. in 2 4hrs.	No. germs per c.c c. in 48 hrs.	No. germs per c. c. in 72 hrs.	No. germs per c. c. in 5 days.
B. ramosus.....	7	87,000,000	20,000,000	11,000,000	14,000,000
Ps. radicicola alfalfa.....	86	80,000	125,000,000	*2,000,000	7,000,000
B. ramosus.....	7	48,000	7,000,000	5,000,000	2,000,000
+					
Ps. radicicola alfalfa.....	86	0	0	0	0

* Flask contaminated.

SERIES IV.

Name of organism.....	No. germs introduced.	No. germs per c. c. in 24 hrs.	No. germs per c. c. in 48 hrs.	No. germs per c. c. in 72 hrs.	No. germs per c. c. in 96 hrs.
B. ramosus.....	9	52,000,000	109,000,000	15,000,000	10,000,000
Ps. radicicola alfalfa.....	39	19,600	152,000,000	600,000,000	1,100,000,000
B. ramosus.....	9	27,000,000	9,000,000	5,000,000	6,000,000
+					
Ps. radicicola alfalfa.....	39	0	0	0	0

An examination of the above four series will show that where the alfalfa germ was grown in pure culture, there was always an increase in the number of germs throughout the experimentation period; that where the alfalfa germ and B. ramosus were associated in the same flask, in no single instance did any of the alfalfa organisms show growth at any time during the experiment while the B. ramosus did grow and multiply although not in as great numbers as when in pure culture.

So far as this experiment goes there seems to be a marked antagonism towards the alfalfa and whether it is to be considered as mere inhibition or death remains to be demonstrated later. In conclusion it may be well to state that although there is a very decided loss and apparent destruction of the alfalfa germ at the hands of B. ramosus when grown in a culture medium in a flask, we are not safe in drawing any conclusions whatever as to the relation of these organisms to one another in the soil for in all probability, as some of our experiments now in progress seem to indicate, these toxic products, whatever they may be, are in some way neutralized, transformed or absorbed by the soil, the conditions of the field being so different from those of the flask.

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TWENTY-FIVE YEARS OF BIRD MIGRATION AT ANN ARBOR, MICHIGAN.

NORMAN A. WOOD.

(From the University Museum, University of Michigan.)

The following first-arrival records of the spring migration were made in the vicinity of Ann Arbor, Michigan, during the past 25 years. With few exceptions these records have been taken in the area included within the Ann Arbor topographic sheet of the U. S. Geological Survey. This area has been described by Transeau (Bot. Gaz., Vol. XL, pp. 351-356), and from which the following account is taken: "There are, then, three natural divisions of the Huron drainage basin: (1) the loose-textured rough interlobate moraine; (2) the clay morainic belt lying to the southeast of it; (3) and the low-lying plain extending to Lake Erie. Each implies important differences in the way of bog formation and provides edaphic factors which determine to a large extent the nature of the dominant forest covering." These divisions have a marked influence upon the bird life. The first division is composed of "morainic knobs, lake basins, abandoned glacial drainage channels, and sand plains." This area extends down the Huron river to just below Portage lake. Its characteristic forest is composed of certain oaks, associated northward with some pine and many groves of tamarack. "These tamarack areas are to be seen on all sides in the region of the interlobate moraine; they are quite common in the clay morainic belt, but are practically wanting on the lake plain." The second division, the clay morainic belt, extends obliquely northeast and southwest nearly parallel to the first and reaches along the Huron river from near Portage lake to Ypsilanti, nine miles southeast of Ann Arbor. Most of my early records were made near Saline, Mich., which is near to a broad glacial valley extending south and west from Ann Arbor to Adrian. This channel is apparently today a migration route, and a breeding place for a number of species which seem to be extending their range northward. It is here that many of the records of the more southern species have been made, such as the Yellow-breasted Chat; Henslow's, Leconte's and Lark Sparrows; Swallow-tailed Kite, and also the Turkey Vulture which has been found breeding near Macon. Many records have been made about three miles east of Ann Arbor on the Huron river at what is locally known as the "Overflow." This is a low swamp area nearly covered by the back waters from a dam built at Geddes. This region affords a variety of conditions and is a very favorable one for the study of many species. This spot has been quite thoroughly worked for many years and has afforded many rare records for the vicinity.

The third division—the lake plain area—extends from Ypsilanti eastward, and is a glacial lake plain gently sloping southeastward from the morainic belt just described, to the western shore of Lake Erie.

On this lake plain we find the richest mesophytic forest of this vicinity,—a continuation, according to Transeau, of the northern Wabash valley flora. It is not therefore surprising that there should occur some of the more southern birds with this forest. I have found here the Cardinal, the Tufted Titmouse, and below Ypsilanti the Sycamore Warbler has been taken by Dr. J. Van Fossen in the groves of sycamores which line the river.*

From this sketch of the region under consideration, it will be seen that the conditions are very favorable for the occurrence, not only of the common bird life of the State, but also for many of the rarer species which find favorable conditions and in some cases breed in this vicinity, as with the Prothonotary Warbler, which was found in a swamp near South Lyon.

Ann Arbor is particularly fortunate with regard to bird migration, in being situated at the junction of the Huron valley and the old glacial drainage channel which extends southwest, which, by means of the lake plain, connects with the Maumee and Wabash valley systems, thus furnishing a highway for certain species. The water birds probably migrate up the Huron valley from Lake Erie, past Ann Arbor and on to the northwestern lake region.

The marginal notes in my personal copy of Coues' "Key" are the first records which I have of the occurrence of species in this vicinity, near Saline, eight miles southwest of Ann Arbor. In the year 1884 I commenced a regular series of records on blanks sent out by the American Ornithologists' Union. These were sent to me by the late Dr. J. M. Wheaton, then of Columbus, Ohio, who had charge of the inland division. The blanks were later (1886) sent out by the U. S. Dept. of Agriculture, "Division of Ornithology and Mammalogy," and in 1896 by the Mich. Ornithological Club. Since 1895 the records include the observations of several bird observers, most of whom were students here at the University.

During the last three years the members of the Bird Club, an informal club under the auspices of the University Museum, have furnished the records. It will be seen that these later records are the most complete of the series, on account of the larger number of observers. Of the local students especially active in making the records, the following should be mentioned: W. A. Maclean, Jesse J. Ricks, A. D. Tinker, W. H. Grant, Otto McCreary, R. A. Brown, Max M. Peet and R. D. T. Hollister.

We are under special obligations to Prof. W. W. Cooke of the Biological Survey of the U. S. Department of Agriculture, for allowing Mr. W. H. Grant to make a copy of certain early records sent in by Ann Arbor observers. The various records available include the following lists: 1886, by Prof. J. B. Steere and students; 1888, by Prof. F. L. Washburn; 1889, by Mr. A. B. Covert, who also kindly allowed the use of many marginal notes in his copy of Coues' Key; 1890, by Mr. Jas. Savage; 1892, by Mr. Legrand T. Meyers; 1899, by Mr. Chas. L. Cass (spring and fall); 1884, 1886 and 1892, by myself at Saline, copies of which I had not preserved. For those records we are under special obligations to Mr. Grant.

*On April 22, 1906, I saw this warbler in a sycamore grove near Geddes, and on May 4 secured a pair. I believe this is the most northern record for Michigan.

On account of the scattered nature of these records, the liability of their being lost and their present inaccessability to students, I have been instructed by Mr. Chas. C. Adams, the Curator, to prepare in tabulated form the following records, and I am indebted to him for many suggestions in their preparation. The nomenclature, and numbers in parenthesis are those of the A. O. U. Check List. In the first column of the following tabulation is given the earliest recorded date of arrival, in the second, the average date of arrival for each species, and in the following columns the earliest date for each consecutive year.

This list includes all the species observed in this vicinity, and the number of records for each species shows whether it is common or rare. The lack of data for the water birds is owing to the fact that very little work has been done in the interlobate lake area, which region affords the best opportunity for securing such records.

The occurrence of the following species not included in the list, should be considered hypothetical: Brewster's Warbler is placed here as it is thought to be a hybrid. The Labrador Duck is also placed in this list. The following species are placed in the doubtful list: Little Blue Heron, Richardson's Merlin, Hoary Redpoll, Smith's Longspur, Blue Grosbeak, Hooded Warbler, Kentucky Warbler, White-eyed Vireo, Belted Piping Plover, Hudsonian Curlew, and Sabine's Gull.

The method of determining the average dates of arrivals is as follows:

I. For species having a wide range of dates, the week including the greatest number of records was chosen, thus: March, second week.

II. For species whose range of dates is limited, though variable, the average date is given as: April 5 a.

III. For the few species which have arrived at a definite date, the exact record is given, as: May 5.

GENERAL REMARKS.

The *Table of First Arrivals* is placed at the end of this paper and is a record of all first arrivals from 1880 to 1905 inclusive.

In addition to the *Table of First Arrivals* two other tabulations have been prepared to show further details of the spring migration. One is a *Table of Migration Waves,* to show for each week the dates and number of species occurring in each wave, and the number of species arriving during each week. The second is a *Table of Species Occurring on more than one Wave,* and is intended to show the number of waves for each week and the number of dates of first arrivals for each species during the twenty-five years. Although but a very rough estimate, when more than three species have arrived on the same date, this has been considered a wave. For the exact date of arrival the *Table of First Arrivals* should be consulted.

TABLE OF MIGRATION WAVES.

Month.	Week.	No. of years.	Year.	Day.	No. of species.
March	First	3	1887	7	3
			1894	3–5	10
			1896	7	5
	Second	1	1889	10–11	7
	Third	1	1905	16	5
	Fourth	1	1886	30	6
April	First	5	1885	1	5
			1888	2–7	9
			1890	3–5	9
			1896	1	4
			1900	1	3
	Second	4	1888	14	6
			1889	11	6
			1890	12	9
			1896	10	4
	Third	4	1886	19	4
			1890	19	3
			1899	19–20	13
			1900	15	8
	Fourth	8	1886	24	3
			1888	28	8
			1890	22	4
			1896	23	7
			1899	25–26	12
			1900	28	6
			1902	30	4
			1904	24	9
May	First	12	1886	1–6	14
			1888	5	8
			1889	4–7	15
			1890	3–4	18
			1892	2–3	9
			1896	5	20
			1900	2	13
			1901	4	5
			1902	2–4	17
			1903	7	7
			1904	6–7	12
			1905	2–7	28
	Second	5	1889	12	7
			1890	8	3
			1900	8	4
			1901	11	5
			1903	7	7
	Third	3	1887	19	6
			1888	19	9
			1889	17	5

TABLE OF SPECIES OCCURRING ON MORE THAN ONE WAVE.

Month.	Week.	Names of species.	No. of waves.	Frequency of first arrivals.
March	First	Bluebird	2	8
		Bronzed Grackle	2	6
		Meadow Lark	2	7
	Fourth	Phoebe	0	7
April	First	Phoebe	3	3
		Cowbird	3	5
		Tree Swallow	3	3
		Vesper Sparrow	2	2
	Second	Fox Sparrow	3	3
	Third	Wilson's Snipe	2	3
		Ruddy Duck	2	2
		Brown Thrasher	2	7
		Whip-poor-will	2	2
		Tree Swallow	2	2
	Fourth	Myrtle Warbler	0	7
		Baltimore Oriole	3	12
		Blue-gray Gnatcatcher	2	11
		White-throated Sparrow	2	6
		Yellow Warbler	3	10
		Red-headed Woodpecker	2	7
		Least Flycatcher	0	6
May	First	Red-headed Woodpecker	2	4
		Whip-poor-will	2	6
		Bobolink	7	9
		Myrtle Warbler	3	4
		Palm Warbler	9	10
		Least Flycatcher	4	4
		Chestnut-sided Warbler	6	6
		Black-throated Blue Warbler	3	12
		Golden-winged Warbler	4	6
		Orchard Oriole	5	6
	Second	Orchard Oriole	5	7
		Wilson's Warbler	5	3
	Third	Wilson's Warbler	2	3

SUMMARY OF BIRD WAVES.

The period of greatest migration occurs the last week of April and the first week of May. While there are many "first arrivals" for March, there are distinct "bird waves" for three years on the first week, with a total of eighteen species. The second, third and fourth weeks each have only one year with a "bird wave" with a total of eighteen species. The first week of April has "bird waves" for five different years with a total of thirty species, while the second and third weeks have only four waves with totals of twenty-five and twenty-eight species respectively. The fourth week of April has eight waves for eight years with a total of fifty-three species. May, the last month of the migration, gives, during the first week, the greatest number of waves (twelve years), ranging in number from seven species on the seventh of May (1903) to twenty species on the fifth of May (1896), and twenty-one

species on the second of May (1905), or a total of 166 species for the twelve years. The waves for the second week in May occur for five years only, with the total of twenty-six species, while the third week generally finishes the spring migration, and there are only three years of migration waves with a total of twenty species. These records show that the hardier birds, like the Robin, Bluebird, Meadow Lark, Blackbird and many other early migrants do not come at a stated time each year, but are governed in their migration to a certain extent by favorable weather and food conditions.

These records also show that certain later migrants tend to arrive in a given locality at about the same time each year, as for example, the Boblink arrived during the first week of May for nine years; the Palm Warbler has ten first arrival records for the same week, and the Myrtle Warbler, seven. Kirtland's Warbler has been taken only four times at Ann Arbor—on May 14, 15, 16 and 18—which shows a wonderful regularity, while the last migrants, like the Blackpoll, Wilson's, Mourning and Connecticut Warblers may be expected from May 15 to 20. The weather conditions hastening or delaying them for only a few days, while the earlier migrants have a range for arrival of weeks, (and in some cases months), due apparently to weather conditions. In connection with this phase of bird migration it would be interesting to study the weather maps for the past twenty-five years in order to see how closely the bird waves follow the favorable weather conditions. There can be little doubt but that the birds take advantage of the conditions that seem to be the most favorable for their successful migration, and enough study of the weather maps has been done at this Museum to show that "bird waves" can be predicted with some certainty. The *Table of Species* shows that many arrive here with remarkable regularity, irrespective of the bird waves. For instance, the Phoebe has seven arrival records for the fourth week of March which has no recorded bird wave; the Brown Thrasher has seven first arrival records for the third week in April (which has records for four bird waves in four years), only two of which this species took advantage; the Baltimore Oriole has twelve arrival records for the fourth week in April, which has eight waves, only three of which is used; the Blue-gray Gnatcatcher is another with eleven first arrivals, but came on only two of the eight waves; and the Yellow Warbler has ten first arrivals for the same week, and it came on only three waves. The first week in May has bird waves for twelve years, and of these the Whip-poor-will took advantage of but two, although it has six arrival records for that week. The Bobolink with nine arrival records for the same week came on seven of the twelve bird waves, and the Palm Warbler, with ten arrival records, used nine of the twelve waves. The Chestnut-sided Warbler has only six arrival records for this week, but came every time on a wave. While the Black-throated Blue Warbler with twelve arrival records came on only three of the twelve waves. These instances refer, of course, to only the first recorded arrivals. The bulk of the species may have arrived on a bird wave, as it is a well-known fact that the first arrivals, as a rule, are adult males, which appear from five to twelve days in advance of the females and immature birds.

No. 1. Table of First Arrivals.

	A. O. U. Nos.	Common name of bird.	Earliest record.	Average arrival.	1880.	1881.	1882.	1883.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	
1	(3)	Horned Grebe	I–10–1902	III–20a	IV–19																			II–19	III–30		I–10	IV–20	II–20		1
2	(4)	American Eared Grebe	I–10–1879		IV–29	V–2																									2
3	(6)	Pied-billed Grebe	IV–2–1905	IV–Second week																											3
4	(7)	Loon	IV–3–1890	IV–Second week	V–15											IX–15				X–10		V–22		IV–20	VI–20			IV–20	IV–10	IV–2	4
5	(11)	Red-throated Loon	IV–15–1880		IV–15						IV–8	IV–21	IV–6		IV–3						V–12	VI–3						IV–10	IV–16	IV–22	5
6	(51)	Herring Gull	II–28–1904	III–22a																											6
7	(58)	Laughing Gull	IV–12–1880		IV–12						IV–8	IV–21									III–15			IV–19					II–28	III–10	7
8	(60)	Bonaparte's Gull	IV–19–1889	V–Second week	IV–21	V–5								IV–19																	8
9	(62)	Sabine's Gull	XI–17–1880		XI–17																			IV–19				V–10	V–8		9
10	(70)	Common Tern	V–8–1904	V–Second week												V–10												V–23	V–8		10
11	(74)	Least Tern	V–4–1875																												11
12	(77)	Black Tern	V–18–1904	V–Second week		[June 5,	1875]										V–19														12
13	(120)	Double-crested Cormorant	IV–12–1875																			XI–15			XI–25			V–22	V–18		13
14	(125)	American White Pelican	X–4–1878																												14
15	(129)	American Merganser	I–5–1904	III–First week				II–17			IV–3	I–24	III–10	III–1											III–4		III–4	III–9	I–5	III–24	15
16	(130)	Red-breasted Merganser	I–15–1905	III–Second week																				III–25	IV–15			IV–20		I–15	16
17	(131)	Hooded Merganser	III–15–1888	III–21																											17
18	(132)	Mallard	II–20–1904	III–Fourth week							IV–3		III–15																		18
19	(133)	Black Duck	IV–6–1890						III–25				III–25				X–15							IV–10	III–23		III–30		III–26		19
20	(137)	Baldpate	III–28–1889												IV–6												V–30		II–20	III–10	20
21	(139)	Green-winged Teal	III–20–1902	III–23a										III–28															IV–16		21
22	(140)	Blue-winged Teal	III–24–1888	IV–13a										III–23																	22
23	(142)	Shoveller	IV–20–1899										III–24														III–20		III–25		23
24	(143)	Pintail	II–17–1890										IV–8											IV–20							24
25	(144)	Wood Duck	II–17–1890	III–First week		IV–1				IV–1	III–21		III–17	III–16	II–17						III–21			IV–20							25
26	(146)	Redhead	IV–10–1902											III–16	II–17		II–17		III–5							XI–1		X–8	IV–2	26
27	(147)	Canvas-back	III–25–1904																								IV–10				27
28	(148)	American Scaup Duck	III–22–1889	IV–30																									III–25		28
29	(149)	Lesser Scaup Duck	III–20–1896	IV–Third week										III–22	IV–19								V–5						V–2	V–12	29
30	(150)	Ring-necked Duck	IV–5–1878																		III–20										30
31	(151)	American Golden-eye	III–5–1904	III–Second week																											31
32	(153)	Buffle-head	III–23–1889	IV–Second week						IV–1	III–20	IV–21	III–28	III–13											IV–15				III–5	III–19	32
33	(154)	Old-squaw	XII–10–1901											III–23							IV–23				IV–21				IV–16	IV–2	33
34	(156)	Labrador Duck	IV–17–1872																							XII–10		V–2			34
35	(165)	White-winged Scoter	X–29–1881			X–29																									35
36	(166)	Surf Scoter	XI–21–1887		[IV–15	1869]						XI–21																			36
37	(167)	Ruddy Duck	IV–10–1880	IV–Third week	IV–10																										37
38	(172)	Canada Goose	II–26–1887	III–First week											IV–19	V–5															38
39	(180)	Whistling Swan	III–7–1903	III–Last week				III–14	III–15	III–31	III–4	II–26	III–15	III–13			III–14	III–3	III–5		III–7			IV–20							39
40	(190)	American Bittern	IV–6–1903	IV–Third week			V–5								IV–10			IV–28		VI–1	IV–20	IV–20		II–28	III–8		III–5	III–7	III–23	III–13	40
41	(191)	Least Bittern	IV–29–1904	V–First week																							III–23	III–7	IV–8		41
42	(191.1)	Cory's Least Bittern	VIII–8–1894															V–12	V–12	VI–14		VI–4			IV–20		V–2	IV–6	IV–22	IV–23	42
43	(194)	Great Blue Heron	III–4–1902	III–Third week						IV–7	IV–13		IV–15	III–19	III–20		III–20		VIII–8										IV–29		43
44	(196)	American Egret	IV–20–1895			[VIII–17	1878]			VIII–10	VII–12		VI–22							V–15	III–30			III–25	IV–15		III–4	V–2	III–16	III–23	44
45	(197)	Snowy Heron	V–10–1889										VII–22	V–10						IV–20											45
46	(200)	Little Blue Heron	V–1876																												46
47	(201)	Green Heron	III–19–1904	IV–Fourth week		IV–20				IV–30																					47
48	(202)	Black-crowned Night Heron	IV–30–1894															IV–30	IV–30		IV–23	IV–22					IV–30	V–13	III–19	V–5	48
49	(204)	Whooping Crane	VI–8–1877																IV–30												49
50	(206)	Sandhill Crane	V–2–1878		V–30																	V–25			X–25						50
51	(203)	King Rail	V–12–1893																												51
52	(212)	Virginia Rail	V–2–1905	V–10a	V–5								XI–5					V–12	V–12	VIII–19											52
53	(214)	Sora	IV–19–1899	V–First week														V–7		VI–14	VI–5			V–13							53
54	(215)	Yellow Rail	IX–13–1877														VI–5	IV–30	IV–30		V–5	V–22		IV–19						V–2	54
55	(216)	Black Rail	VI–4–1880		VI–4																									V–3	55
56	(219)	Florida Gallinule	IV–23–1902	V–10a																											56
57	(221)	American Coot	IV–17–1904	IV–25a											V–9		V–6	V–7	V–12	V–11	V–5	V–22					IV–23		V–4		57
58	(223)	Northern Phalarope	V–1–1873																	V–1		V–5						IV–17	IV–17	IV–21	58
59	(224)	Wilson's Phalarope	IV–1–1887										IV–1																		59
60	(226)	Black-necked Stilt	X–14–1880		X–14																						IV–30		V–15		60
61	(228)	American Woodcock	III–10–1897	III–Third week				IV–13			III–17	III–20	IV–5	III–27																	61
62	(230)	Wilson's Snipe	III–6–1879	IV–First week			IV–8	IV–18	III–24		IV–18		III–24	IV–3		VII–20		IV–20		V–4	III–20	III–10			IV–4			III–19	III–27	V–2	62
63	(233)	Stilt Sandpiper	V–4–1877															VIII–10				III–30		IV–10	IV–1			III–14	IV–7	III–23	63
64	(234)	Pectoral Sandpiper	IV–30–1890	V–First week											IV–30			VIII–10						IV–20							64
65	(241)	Baird's Sandpiper	VIII–15–1893	VIII–15														VIII–15												V–7	65
66	(242)	Least Sandpiper	V–7–1889	V–Third week									V–19	V–7																	66
67	(243a)	Red-backed Sandpiper	V–14–1888	V–14									V–14					V–16				VI–26									67
68	(246)	Semipalmated Sandpiper	IV–7–1889	V–15a										IV–7			IV–1														68
69	(249)	Marbled Godwit	V–5–1880	V–5	V–5																								V–28		69
70	(254)	Greater Yellow-legs	V–5–1900	V–5a															X–5			V–6			V–5						70
71	(255)	Yellow-legs	V–4–1900	V–5a																											71
72	(256)	Solitary Sandpiper	IV–30–1900	V–7a										V–9	V–19					VIII–15		V–5	V–5		V–4						72
73	(258)	Willet	V–10–1900	V–10																V–4				IV–20	IV–30			V–3		V–12	73
74	(261)	Bartramian Sandpiper	III–15–1896	IV–Second week		V–2	V–20			IV–29	IV–14	III–18	V–10	IV–18			V–3		III–17		III–15	III–28		IV–19	V–10						74
75	(263)	Spotted Sandpiper	IV–16–1905	V–First week							V–6		V–5	V–1	V–3			III–16	IV–28	IV–27	V–1				IV–28				IV–3	IV–23	75
76	(264)	Long-billed Curlew	VIII–12–1893			[IX–12	1872]											VIII–12								IV–20					76
77	(265)	Hudsonian Curlew	VIII–1876																												77
78	(270)	Black-bellied Plover	X–5–1876																												78
79	(272)	American Golden Plover	III–3–1893	IV–Third week	X–5		X–12							III–17	IV–20																79
80	(273)	Killdeer	III–2–1904	III–Second week		IV–22				IV–6	III–10	III–8	III–20	III–16	III–13	V–1	III–13	IV–5	III–5	VI–14	III–8	VI–11						III–24	III–11	III–2	III–16	80
81	(274)	Semipalmated Plover	V–16–1893																												81
82	(277a)	Belted Piping Plover	IV–1878															V–16													82
83	(283)	Bob-white	Resident		XII–13	X–2	X–5	XI–10	X–6	XI–5	X–15	X–20	XI–2	X–6	X–10	XI–15	X–7	X–15	X–20	XI–5	XI–10	XI–7	XI–15	XI–20	XI–15	X–30	X–25	X–20	X–15	V–13	83
84	(300)	Ruffed Grouse	Resident		X–12	X–19	X–20	XI–5	X–10		XI–12	X–16	X–20	XI–18	X–21	X–18	X–15	X–26	XI–5	XI–10	X–26	XI–16	X–20	XI–20	X–20	XII–20	X–20	X–15	XI–1	V–12	84
85	(305)	Prairie Hen	Resident		[X–1872]	[V–10	1875]		[X–1876]																			XI–28			85
86	(310)	Wild Turkey	Extinct		[XI–26	1871]		[XI–19	1880]	[XI–19	1876]		[XII–5	1883]																	86
87	(315)	Passenger Pigeon	Very rare		IX–6	[V–74]		IV–2	[X–12	1875]			XI																		87
88	(316)	Mourning Dove	I–11–1899	II–Third week	II–20	III–16						III–19						X–	IX–27											X–1	88
89	(325)	Turkey Vulture	IV–20–1899	IV–Third week	VI–4						IV–22		IV–21	V–				V–12		IV–6	IV–22	IV–20		V–20	I–11	VII–8			II–20	III–19	89
90	(327)	Swallow-tailed Kite	VIII–15–1886								VIII–15								VI–16		V–20				IV–20			IV–21	IV–22	V–13	90
91	(328)	White-tailed Kite	IX–19–1878																												91
92	(331)	Marsh Hawk	I–10–1902	III–Third week					V–10				III–30		IV–12				III–5												92
93	(332)	Sharp-shinned Hawk	III–18–1903	III–15a							IV–22										V–5				IV–15		I–10	IV–28	III–15	IV–25	93
94	(333)	Cooper's Hawk	I–24–1904	IV–Third week								IV–23		III–10	V–8					V–9	V–1	V–12						III–18	III–23	IV–22	94
95	(334)	American Goshawk	II–17–1875																				XI–20	IV–4			IV–19	XII–1	I–24	III–27	95
96	(337)	Red-tailed Hawk	III–6–1899	III–12a	III–20		V–5	III–10		III–6	IV–3	III–15		III–8			V–5		III–16		III–20	III–10		III–6		III–8		IV–2	III–15	III–23	96
97	(339)	Red-shouldered Hawk	III–10–1883	III–Third week		V–10		III–10			IV–3										III–20	III–20						IV–16	III–11	III–16	97
98	(342)	Swainson's Hawk	V–5–1880		V–5															V–1							IV–30				98
99	(343)	Broad-winged Hawk	IV–15–1905	V–First week												IX–25			IV–21		V–28	V–12									99
100	(347)	Rough-legged Hawk	I–2–1888										I–2								VII–12	II–10	X–10	X–3		VI–25				IV–15	100
101	(349)	Golden Eagle	II–15–1890				XI–27								II–15		VIII–10					XII–15		III–20				X–15		II–23	101
102	(352)	Bald Eagle	I–2–1874		X–5		X–10				II–23																				102
103	(156)	Duck Hawk	III–10–1884	IV–15					III–10	VIII–29			III–11	IV–21															V–30		103
104	(357)	Pigeon Hawk	III–I–1896	IV–First week	IV–16						III–30	X–3	III–12	IV–2	X–19						III–1	IV–10			XI–5				IV–27		104
105	(358)	Richardson's Merlin	Fall–1859																												105
106	(360)	American Sparrow Hawk	I–23–1899	IV–15a	IV–2								IV–14	IV–13					V–5		III–10	IV–17						III–31	I–23	II–1	106
107	(364)	American Osprey	III–10–1905	IV–Second week																V–20	IV–10		V–15	VIII–11	V–22			IV–28	IV–9	III–10	107
108	(365)	American Barn Owl	V–13–1900		[V–1879]										X–15		XI			VIII–20			X–15		V–13				XII–12		108
109	(366)	American Long-eared Owl	Resident		[IV–1879]						II–4														II–5						109
110	(367)	Short-eared Owl	II–5–1905															XII–1							XII–1	II–26	II–10		II–16	II–5	110
111	(368)	Barred Owl	Resident		II–6			II–14			I–6	IV–21			XII–5																111
112	(372)	Saw-whet Owl	Resident	[V–23–1879]	I–1	I–10		[V–27	1873]														X–5	V–5				XI–10		I–4	XI–6	112
113	(373)	Screech Owl	Resident		I–1	I–10	II–6	X–16	XII–8	III–5	XI–20	X–10	II–4	I–26	II–17	III–3	V–7	X–10	I–23	II–16	III–7	VI–10	X–5	X–20	XI–5	XII–8	I–5	II–18	III–17	V–11	II–1	113
114	(375)	Great Horned Owl	Resident		II–5			III–6					IV–23	I–16						XI–1				XII–17				III–17		I–4	114
115	(376)	Snowy Owl	XII–15–1905						I–2					I–5													IV–30	X–25		III–10	115
116	(377a)	American Hawk Owl	XII–5–1886								XII–5																II–10		XII–25	XII–15	116
117	(387)	Yellow-billed Cuckoo	V–6–1904	V–First week						V–5	V–15	V–19	V–22	V–12			V–22	V–12													117
118	(388)	Black-billed Cuckoo	V–12–1889	V–Second week				IX–15		VI–10	V–20	V–19		V–12			V–20	V–6				VI–10						V–7	V–10	V–6	V–13	118
119	(390)	Belted Kingfisher	II–15–1896		[III–22	1879]		III–4			III–6		III–18	II–26	IV–5			VI–20						V–16			V–14	V–14	V–13	119
120	(393)	Hairy Woodpecker	Resident		I–10	II–5	IV–12	III–6	V–10	X–2	III–8	I–7	V–3	VII–1	X–6	VII–20	III–16	XII–20	V–6	IX–27	II–8	IV–5	I–20	XI–22	III–26	X–17	VIII–10	XI–25	II–27	I–1	120
121	(394)	Downy Woodpecker	Resident		III–6	V–7	II–22	I–28	III–7	V–6	VI–4	VII–8	X–5	XII–1	VIII–6	II–10	IV–6	XII–20	II–27	III–30	II–29	I–28	IV–6	X–30	II–27	III–6	I–20	XII–19	III–1	I–1	121
122	(400)	Artic Three-toed Woodpecker		I–26–1881		I–26																									122
123	(402)	Yellow-bellied Sapsucker	III–25–1904	IV–Second week	[IV–8	1879]		IV–10		V–22	IV–18		IV–14		IV–12									IV–20	IV–10		III–27	IV–7	III–25	III–28	123
124	(405)	Pileated Woodpecker	Resident		[XI–13	1872]		[X–15	1875]															III–1							124
125	(406)	Red-headed Woodpecker	III–10–1883	IV–Third week				III–10		V–5	III–4	IV–26	IV–26	V–5	IV–12	VII–20	IV–28	V–9		V–4	III–15	V–23			V–4				IV–9	IV–24	III–10	125
126	(409)	Red-bellied Woodpecker	III–22–1889	III–Third week		XII–15						VI–5	V–5	III–22			III–5			VI–I	V–1						XI–28	IV–20		V–6	126
127	(412)	Flicker	I–1–1905	IV–First week	II–6	IV–21	III–10	IV–8	V–20	VI–1	I–20	IV–7	VI–5	III–8	IV–3	III–26	IV–1	V–13	VI–8	XII–4	IX–12	X–6	VII–3	IV–4	XI–14	V–3	IV–18	III–31	I–4	I–1	127
128	(417)	Whip-poor-will	IV–17–1899	V–First week		V–8		V–7			IV–19	V–16	V–5	V–7			V–25	V–13		V–20	V–5	IV–25		IV–17	IV–23		V–7	V–21	V–1	V–14	128
129	(420)	Nighthawk	V–1–1888	V–12a		VI–5					V–15		V–1	V–8			V–20		V–2		V–20			V–14	V–14			V–23	V–1	V–11	129
130	(423)	Chimney Swift	IV–2–1889	V–First week			IV–21	IV–29	IV–21	IV–26	IV–17	V–1	V–1	IV–2	V–3		IV–30	V–1	V–1		V–20			IV–26	V–20	V–10	IV–26	IV–20	IV–9	IV–20	130
131	(428)	Ruby-throated Hummingbird	V–1–1889	V–First week	[V–9–79]	V–20	V–4	V–14	V–6	V–21		V–19	V–5	V–I	V–8					V–4	V–4	V–5	V–1					V–8	V–15	V–7	V–4	131
132	(444)	Kingbird	IV–20–1893	V–First week		V–3	V–5	V–10			IV–28	V–14	IV–28	V–2			IV–24	IV–20		V–16	V–2			IV–25				V–2	V–1	V–3	III–23	132
133	(452)	Crested Flycatcher	IV–19–1896	V–First week		V–16		V–16			IV–30		V–5	V–10	V–3			V–6	V–6	V–10	IV–19	V–12			V–8			V–7	V–1	V–4	V–3	133
134	(456)	Phebe	II–23–1886	III–Third week	III–15		III–30	IV–8	III–1	III–1	II–23	III–7	III–24	III–24	III–22		III–24	III–16	III–16	III–30	IV–1	III–23			III–8	IV–1	III–10		III–1	III–20	III–16	134
135	(459)	Olive-sided Flycatcher	V–1–1903	V–14a																	V–28								V–1		135
136	(461)	Wood Pewee	V–5–1896	V–8a	V–5		V–11		V–4		V–12		V–6	V–8		V–8		V–6	V–6	V–10	V–5	V–12			V–11		V–8		V–14	V–6	V–12	136
137	(463)	Yellow-bellied Flycatcher	V–5–1895	V–10a																V–5		V–12									137
138	(465)	Green-crested Flycatcher	V–11–1904	V–13a										V–15				V–6	V–6		V–15	V–12			V–11		V–15		V–23	V–11	V–7	138
139	(466)	Alder Flycatcher	V–5–1896	V–17a	[VI–10	1875]														V–24	V–5	V–12						V–19	V–17		139
140	(467)	Least Flycatcher	IV–5–1902	IV–Fourth week		V–17					IV–26		IV–28		V–4			IV–30	IV–30	V–4	V–5	V–12						IV–30	IV–5	IV–25	IV–30	140
141	(474b)	Prairie Horned Lark	II–9–1889	III–First week	III–5		III–8	III–20			I–6	II–9			IV–1			III–23	II–29	II–5	III–3					IV–1		III–18	II–24	III–7	141
142	(477)	Blue Jay	Resident		II–6	IV–4	XI–25	X–20			II–26	I–20	X–15	III–1	IV–6	II–22	XI–16	IX–20	VII–1	X–4	IV–8	VIII–1	II–15	VII–20	III–30	III–17	I–16	I–1	142
143	(480a)	Northern Raven	Extinct		[III–30	1875]	[III–20	1878]					XI																		143
144	(488)	American Crow	II–6–1903	II–Fourth week	III–1	I–20	III–5	II–25		II–10	II–22	III–6	III–1	II–16	II–25	III–3	III–2	II–10	X–16	II–21	IV–15	III–12	II–19	III–10	II–27	III–4	II–6	II–24	II–24	144
145	(494)	Boboliak	III–10–1894	IV–First week	[V–9	1879]	IV–29	V–9		IV–30	IV–12	V–I	IV–25	V–4	V–2		V–2	IV–28	III–10	V–4	V–5			V–6	IV–26		V–3		V–12	V–1	III–28	145
146	(495)	Cowbird	I–27–1904	IV–First week	IV–2		IV–13	IV–8	II–18		IV–3		IV–2	III–10	IV–3		IV–6	III–17	III–17	IV–6	IV–15			IV–6	III–2	IV–1		IV–1	IV–5	I–27	III–24	146
147	(498)	Red-winged Blackbird	II–22–1887	III–First week	II–28	IV–2	II–27	III–2	II–22	III–7	III–7	II–22	III–10	III–4		III–5	III–5	III–4			IV–25			III–12	III–20		III–8	III–9	III–8	III–8	III–17	147
148	(501)	Meadow Lark	I–4–1887	III–First week	III–5	IV–18	II–18	V–2	III–29	III–4	I–4	III–2	III–2	III–6	II–5	III–3	III–3	III–22	III–6		III–6			III–4	I–9	III–19	III–7	I–4	II–22	III–2	III–16	148
149	(506)	Orchard Oriole	IV–23–1895	V–Second week		V–23	V–4	V–10	V–22	V–10	V–10	V–10	V–10	V–6	V–22		V–22		V–4	IV–23	V–10				V–8	V–6		V–2	IV–25	V–8	V–7	149
150	(507)	Baltimore Oriole	IV–6–1894	IV–Fourth week	IV–30	V–13	V–5	V–1		V–1	IV–29	IV–30	IV–25	IV–22	IV–30		V–8	V–1	IV–6		V–5			IV–28	IV–25	IV–29		V–1	IV–25	IV–28	IV–30	150
151	(509)	Rusty Blackbird	III–7–1893	III–13a			III–3	III–20					III–24																		151
152	(511b)	Bronzed Grackle	II–27–1896	III–First week	[III–29	1879]	III–10	III–15	III–18	III–28	III–18	III–28	IV–28	III–14	III–4		III–5	III–6	III–6	III–22	II–27			III–4	III–11		III–6		III–9	III–2	III–16	152
153	(514)	Evening Grosbeak	XII–3–1886	[Winter of 1879]								XII–3	IV–30	XII–	IV–12												IV–15			I–17		153
154	(515)	Pine Grosbeak	XI–7–1903			I–11								IV–13	IV–22		V–7	IV–23											XI–7	I–1		154
155	(517)	Purple Finch	II–1–1905	III–Last week		V–14		III–15			V–13	V–1	III–24	IV–10					II–13		V–8								V–7	III–14	II–1	155
156	(521)	American Crossbill	X–1–1890	[III–18–1869]	V–15			V–11		IV–30		X–25	VI–1	XI–29	IV–5						IV–8							X–12				156
157	(522)	White-winged Crossbill	XI–5–1899					III–15							III–19																	157
158	(427a)	Hoary Redpoll	XII–1877																												158
159	(528)	Redpoll	X–4–1832		I–6	III–8	X–4								IV–7					I–10			I–10								159
160	(529)	Americaa Goldfinch	Resident		II–24	III–30	V–9		II–25		IV–5		II–26		III–22		IV–1	II–22	XI–20	III–23					III–25	III–12		V–2	I–4	I–3	I–5	160
161	(533)	Pine Siskin	IV–20–1900				XI–4						III–28	X–19												IV–20			I–23		161
162	(534)	Snowflake	X–20–1899			I–3		II–10			III–31	II–4	I–22		II–1						II–15	III–7		X–20				XII–24	II–7		162
163	(536)	Lapland Longspur	II–10–1885							II–10																					163
164	(537)	Smith's Longspur	III–1877																												164
165	(540)	Vesper Sparrow	II–27–1889	III–Third week			IV–6	IV–8					IV–2	II–27	IV–3			III–18		IV–6	III–25			III–10				III–18	III–4	III–18	165
166	(542a)	Savanna Sparrow	IV–25–1905	V–First week			V–5	V–5											VI–16	V–15								X–18		IV–25	166
167	(546)	Grasshopper Sparrow	IV–23–1896	V–Second week																V–11	IV–23						V–17	V–8	IV–27	V–6	167
168	(547)	Henslow's Sparrow	V–12–1894	V–Second week														V–12	V–12		V–26										168
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NOTES ON THE BIRDS OF THE MICHIGAN FOREST RESERVE.

EARL H. FROTHINGHAM.

The following records were made during two seasons spent by the writer while engaged in a forest survey of the Michigan state reserves. They are confined to the north reserve, an area of about 18,000 acres adjacent to the north end of Higgins Lake in Roscommon and Crawford counties. The list of seventy-four species is without doubt very incomplete, but is offered as a beginning for a more detailed study of the bird life of this region.

The conditions which exist on the reserve are briefly as follows:

The climate of this part of Michigan is moderate, characterized by cool summers and by rather long, cold winters. Frost occurs every month in the year. Precipitation is frequent in both summer and winter and amounts to about thirty-five inches per year.

In common with all of northern Michigan the north reserve possesses a topography of glacial origin. Near the lake the surface is rolling, consisting of long sand ridges with intervening swales and extensive cedar swamps. A short distance north of the lake the country is flat over wide areas which are known as jack pine plains from the frequent occurrence here of this tree. There are numerous potholes scattered through the reserve, two or three of which contain standing water. Drainage is by short creeks into the lake and by a larger one, Beaver Creek, into the Au Sable River, some nine miles to the east.

There formerly existed over a large part of the reserve a heavy stand of White and Norway pine. The almost complete disappearance of these trees is to be attributed less to actual lumbering than to the frequent fires that have since swept over the land. Pine saplings, which are unable to replace burned stems by sprouts, quickly succumb to these fires, while the hardwoods—consisting mainly of oak and maple—send up shoots again and again until their vitality is exhausted, when they in turn give way to the encroachment of sedge, sweet fern, huckleberry and prairie willow.

With the introduction of fire protection, a succession somewhat the reverse of the above is to be expected. As may be noticed at various places through the reserve, spots which for any reason have escaped recent fire will often bear thickets of young popple and fire cherry, the former seeded down by the wind, the latter by birds. Wherever such protected patches occur near pine trees a prolific reproduction of pine is almost sure to take place. Gradually, owing to the greater adaptibility of soil and climatic conditions to pine than to hardwood production, the former type of forest will become dominant, and the hardwoods will once more fill their subordinate position as a stunted undergrowth.

With the types of vegetation which mark the different stages of the plant succession just described there seem to be correlated certain defi-

nite bird forms. These forms are for the most part such as frequent observations in northern Michigan have identified as generally characteristic of the respective environments. As illustrative of the local conditions I have selected some of the more obvious examples of such a correlation.

The vegetational types of the north reserve may be roughly classed as grassland, sweet-fern and willow plains, oak coppice, jack pine woods, cassandra swamp, and timber or "cedar" swamp. Very few of the species observed were frequenters of either grassland, sweet-fern plains, or cassandra swamps; Meadow Larks were confined to the former, while Vesper and Field Sparrows were characteristic of grassland and sweet-fern, usually in the neighborhood of trees or oak brush.

Oak coppice was found to support a more varied bird population. Here the Towhee Bunting was the most conspicuous form and its monotonous song was to be heard wherever this vegetation existed. With it were seen the Goldfinch, Chipping Sparrow, Kirtland's Warbler, Yellow Throat, and House Wren. The one specimen of the Prairie Warbler was seen on this type.

Jack pine woods usually contained a Wood Pewee or two and a number of Flickers, these species seeming to prefer the dry "pine barrens" to any other type. Here were also seen Ruffed Grouse, Black-billed Cuckoos, Hairy Woodpeckers, Blue Jays, Red-eyed Vireos, Oven Birds, Nuthatches, Chickadees, and occasionally Hermit Thrushes.

The timber swamps were the richest of all the types in bird life. Typical of this vegetation were the Whip-poor-will, White-throated Sparrow, Black-throated Green Warbler, Redstart, Winter Wren, and Hermit Thrush. A pair of Mourning Warblers nested each year in the edge of one of these swamps, and a single Canadian Warbler was seen there. The Song Sparrow, Indigo Bird, Downy Woodpecker, Cedar Bird, Oven Bird, Chickadee, Flicker and Ruffed Grouse were quite common frequenters of the swamp edge.

The above brief discussion applies in a general way to a few of the more obvious cases of correlation. What the conditions are which govern these correlations and how they influence the various species is a problem which remains to be worked out in detail. The opportunity for a thorough local study of the reserves is a good one, and data collected from year to year should throw some light on the influence of changing vegetative conditions upon bird life.

ANNOTATED LIST.

1. *Urinator imber.* Loon.—Higgins Lake, 1904-5. Frequently heard and seen on the lake.

2. *Ardea herodias.* Great Blue Heron.—Crawford Co., July 8, 1905. Not common.

3. *Helodromas solitarius.* Solitary Sandpiper.—Crawford Co., August 20, 1904. One seen at "deer lick" (pot hole). Heard frequently 1905.

4. *Actitis macularia.* Spotted Sandpiper.—Crawford Co., shore of Higgins Lake. July 5, 1904, pair seen with young, newly hatched. July 2, 1905, nest of four eggs found.

5. *Colinus virginianus.* Bob White.—Crawford Co., July 6, 1904, heard. July 9, 1905, heard. Occasional. Few are said by the forest ranger to survive the more severe winters.

6. *Bonasa umbellus togata.* Canadian Ruffed Grouse.*—Crawford Co., July 8, 1904, seen. Heard frequently drumming at night. July 3, 1905, seen with young. Common on edge of cedar swamps and in jack pine woods.

7. *Zenaidura macroura.* Mourning Dove.—Crawford Co., July 6, 1905. Heard and seen. July 2, 1906. Not very common.

8. *Circus hudsonius.* Marsh Hawk.—Crawford Co., July 30, August 13, 1904. July 3, 1905. Fairly common.

9. *Accipiter velox.* Sharp-shinned Hawk.—Crawford Co., July 2, 1904. Roscommon Co., August 20, 1904. Common.

10. *Buteo borealis.* Red-tailed Hawk.—Crawford Co., July 25, 1904. Seen flying. July 8, 1905. Commonly seen in or near timber swamps.

11. *Haliaetus leucocephalus.* Bald Eagle.—Crawford Co., July 3, August 24, 1904. July 6, 1905. Frequent along the shores of Higgins Lake.

12. *Falco sparverius.* American Sparrow Hawk.—Crawford Co., July 21, 1904. One seen flying over plains. Roscommon Co., August 20, 1904, about thirty seen in a flock on the shores of Higgins Lake. They remained several days in the vicinity. Crawford Co., July 13, 1905. Common.

13. *Pandion haliaetus carolinensis.* Osprey.—Crawford Co., July 6, 1904, one pair seen flying along lake shore. Infrequent.

14. *Bubo virginianus.* Great Horned Owl.—Crawford and Roscommon Cos., 1904-5. Heard frequently; not seen.

15. *Coccyzus erythrophthalmus.* Black-billed Cuckoo.—Crawford Co., July 10, August 3, 1904; July 2, 1905. Common in jack pines and scarlet oaks; frequent along edges of cedar swamps.

16. *Ceryle alcyon.* Belted Kingfisher.—Crawford Co., July 4, 1904; July 2, 1905. Frequently seen along lake shore.

17. *Dryobates villosus.* Hairy Woodpecker.—Crawford Co., July 5, 1904; July 10, 1904. Frequent, in jack pines and larger oaks.

18. *Dryobates pubescens medianus.* Downy Woodpecker.—Crawford Co., July 21, 1904; July 6, 1905. Frequent in timber swamps.

19. *Sphyrapicus varius.* Yellow-bellied Sapsucker.—Crawford Co., July 5, 1904; July 6, 1905. Infrequent.

20. *Melanerpes erythrocephalus.* Red-headed Woodpecker.—Crawford Co., July 24, 1904. Not common.

21. *Colaptes auratus luteus.* Northern Flicker.—Crawford Co., July 5, 1904; young heard in nest July 11, 1904; July 2, 1905. Common in jack pine and swamp edges.

22. *Antrostomus vociferous.* Whip-poor-will.—Crawford and Roscommon Cos., July 1, 1904; July 2, 1905. Common in swamps.

23. *Chordeiles virginianus.* Nighthawk.—Crawford and Roscommon Cos., July 1, 1904; July 2, 1905. Found nesting in Crawford Co., July 16, 1904; July 3, 1905.

24. *Chactura pelagica.* Chimney Swift.—Crawford Co., July 6, 1904; July 2, 1905. Frequent.

25. *Trochilus colubris.* Ruby-throated Humming Bird.—Crawford Co., July 22, 1904, female seen; July 13, 1905. Frequent.

26. *Tyrannus tyrannus.* Kingbird.—Crawford Co., July 3, 1904; July 2, 1905. Common in oak brush land. Several nests found.

27. *Sayornis phoebe.* Phoebe.—Crawford Co., July 8, 1904, one heard. Not common.

28. *Nuttallornis borealis.* Olive-sided Flycatcher.—Crawford Co., July 4, 1904. Rare.

29. *Contopus virens.* Wood Pewee.—Crawford Co., July 8, 1904; July 3, 1905. Common in jack pines.

30. *Cyanocitta cristata.* Blue Jay.—Crawford Co., July 2, 1904; July 2, 1905. Common.

31. *Corvus brachyrhynchos.* American Crow.—Crawford Co., July 5, 1904; July 2, 1905. Not very common.

32. *Dolichonyx oryzivorus.* Bobolink.—Crawford Co., reported as breeding in Beaver Creek swamp.

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* The variety of this grouse was not determined, but as the specimens obtained in Iosco County in 1903 (Univ. of Mich. Museum, No. 30980; Auk, vol. 22, p. 46) were *togata*, the individuals listed above are probably to be referred to this form. Dorr Skeels, State Forester, reports both *B. umbellus* and *B. umbellus togata* as abundant in Roscommon Co., south of Houghton Lake [Tp. 21, R III W.].

33. *Molothrus ater.* Cowbird.—Crawford Co., July 3, 1904; July 3, 1905. Fairly common; seen mostly about buildings.

34. *Sturnella magna.* Meadowlark.—Crawford Co., July 21, 1904, one seen on grass plains, one mile north of Higgins Lake. July 5, 1905, several seen on the same plains. Not common.

35. *Loxia curvirostra minor.* American Crossbill.—Roscommon Co., August 31 and September 5, 1904, pair seen drinking at windmill in Sec. 17. Infrequent.

36. *Astragalinus tristis.* American Goldfinch.—Crawford Co., July 4, 1904, pair seen. July 2, 1905. Common.

37. *Poocetes graminius.* Vesper Sparrow.—Crawford Co., July 10, 1904; nests found July 18 and 21, 1904, and July 3, 1905. Very common on jack pine plains.

38. *Zonotrichia albicollis.* White-throated Sparrow.—Crawford Co., July 2, 1904; July 2, 1905. Common in timber swamps.

39. *Spizella socialis.* Chipping Sparrow.—Crawford and Roscommon Cos., July 2, 1904; July 2, 1905. Very common. Breeds.

40. *Spizella pusilla.* Field Sparrow.—Crawford Co., July 5, 1904, heard. July 3, 1905. Heard occasionally.

41. *Junco hyemalis.* Slate-colored Junco.—Crawford Co., July 18, 1904, flock seen containing several young birds. July 5, 1905. Frequent.

42. *Melospiza cinerea melodia.* Song Sparrow.—Crawford Co., July 2, 1904; July 2, 1905. Common on edge of timber swamps.

43. *Melospiza georgiana.* Swamp Sparrow.—Crawford Co., August 17, 1904, seen in tamarack "blow-down." Rare.

44. *Pipilo erythrophthalmus.* Towhee.—Crawford and Roscommon Cos., July 2, 1904; July 2, 1905. Very common. Nests in oak-sprout land.

45. *Zameloida ludoviciana.* Rose-breasted Grosbeak.—Crawford Co., August 21, 1904, two seen and heard in tract of virgin pine (Thayer tract).

46. *Cyanospiza cyanea.* Indigo Bunting.—Crawford Co., July 2, 1904; July 2, 1905. Common along eldges of timber swamp.

47. *Piranga erythromelas.* Scarlet Tanager.—Crawford Co., July 10, 1904, male seen in timber swamp. July 10, 1905. Rare.

48. *Hirundo erythrogastra.* Barn Swallow.—Crawford Co., July 5, 1904; July 4, 1905. Frequent.

49. *Tachycineta bicolor.* Tree Swallow.—Crawford Co., July 5, 1905, one seen. Rare.

50. *Riparia riparia.* Bank Swallow.—Crawford Co., July 3, 1905. Occasional.

51. *Ampelis cedrorum.* Cedar Waxwing.—Crawford Co., July 2, 1904; July 2, 1905. Common in timber swamp along lake shore. Breeds in oak brush land.

52. *Vireo olivaceus.* Red-eyed Vireo.—Crawford Co., July 2, 1904; July 2, 1905. Common in cedar swamps and jack pine thickets.

53. *Mniotilta varia.* Black and White Warbler.—Crawford Co., July 24 and August 15, 1904. Males seen.

54. *Helminthophila rubricapilla.* Nashville Warbler.—Crawford Co., July 24 and August 21, 1904. Not common.

55. *Dendroica caerulescens.* Black-throated Blue Warbler.—Crawford Co., August 15, 1904, male seen in timber swamp. Infrequent.

56. *Dendroica pensylvanica.* Chestnut-sided Warbler.—Crawford Co., July 11, 1905. Only one seen.

57. *Dendroica virens.* Black-throated Green Warbler.—Crawford Co., July 2, 1904; July 2, 1905. Common in timber swamps along lake shore.

58. *Dendroica kirtlandi.* Kirtland's Warbler.—Crawford Co., July 6-22, 1904, two pairs seen in scrub oak on a ridge north of Higgins Lake. One pair was apparently nesting. Seen repeatedly at same place for more than two weeks. July 3, 1905, song heard at same place. Roscommon Co., August 25, 1904, male seen.

59. *Dendroica discolor.* Prairie Warbler.—Crawford Co., July 6, 1905, male heard and seen in oak coppice.

60. *Seiurus aurocapillus.* Oven Bird.—Crawford Co., July 6, 1904; July 2, 1905. Common. Cedar swamps and jack pine thickets.

61. *Seiurus noveboracensis.* Water Thrush.—Crawford Co., July 18, 1904. Probably frequent.

62. *Geothlypis philadelphia.* Mourning Warbler.—Crawford Co., July 5, 1904; pair seen repeatedly in timber swamp; probably nesting. July 8, 1905, male seen and heard frequently at edge of swamp; probably nesting.

63. *Geothlypis trichas brachidactyla.* Northern Yellow-throat.—Crawford Co., July 5, 1904; July 2, 1905. Common in oak coppice.

64. *Wilsonia canadensis.* Canadian Warbler.—Crawford Co., August 14, 1904. One specimen seen in timber swamp.

65. *Setophaga ruticilla.* American Redstart.—Crawford Co., July 10, August 14, 1904; July 16, 1905. Frequent in timber swamp along lake shore.

66. *Galeoscoptes carolinensis.* Catbird.—Crawford Co., August 14, 1904; one seen in timber swamp. July 2, 1905. Infrequent.

67. *Toxostoma rufum.* Brown Thrasher.—Crawford Co., July 5, 1904, nesting. July 2, 1905. Frequent in oak brush land.

68. *Troglodytes aedon.* House Wren.—Crawford Co., July 4, 1904, fledged young seen. July 2, 1905. Common in scrub oak.

69. *Olbiorchilus hiemalis.* Winter Wren.—Crawford Co., July 6, 1904; July 2, 1905. Frequent in timber swamp along shore of Higgins Lake.

70. *Sitta carolinensis.* White-breasted Nuthatch.—Crawford Co., July 10, 1904; July 6, 1905. Frequent in timber swamp; seen in jack pine thickets.

71. *Parus atricapillus.* Chickadee.—Crawford and Roscommon Cos., July 5, 1905; August 21, 1904. Observed frequently in timber swamps and jack pine woods.

72. *Hylocichla guttata pallasii.* Hermit Thrush.—Crawford and Roscommon Cos., July 2, 1904; nest with four eggs found July 17, 1904. July 2, 1905. Abundant in edges of timber swamps, also observed in jack pine woods.

73. *Merula migratoria.* American Robin.—Crawford Co., July 5, 1904; July 2, 1905. Frequent. Several nests found in jack pines.

74. *Sialia sialis.* Blue Bird.—Crawford Co., July 5, 1904; July 5, 1905. Frequent. Breeds.

University of Michigan.

A STUDY OF THE BIRDS OF THE OVERFLOW, EAST OF ANN ARBOR, MICH.

R. A. BROWN, M. D.

(From the University Museum, University of Michigan.)

Within the past few years ornithologists have begun to realize the value of locality studies of birds, and such lists have been published in various journals. These studies bring us into the closest touch with the birds, for we have a chance to study their home life, and from a number of such lists we are able to learn the relation between the characteristic habits and the environment. For instance, if we go out into the field today in search of our common Flicker we naturally seek some lightly wooded spot and expect to hear its familiar call from the side of some dead tree or stub, but let us go west to the plains, where one scarcely sees a tree, and we find this same bird hopping about upon the ground, and building its nest in burrows and even flat upon the ground, all due to changes in the environment.

During four years at Ann Arbor I spent much of my spare time in the field, and, as usually is the case, one particular locality appealed to me as the best spot for making observations. That place was a tract covering in a rough way an area about three-fourths of a mile long by a half mile in width, situated along the south bank of the Huron River, and about three miles east of the city of Ann Arbor. This place is commonly divided into two parts by local ornithologists and is spoken of as Blake's Farm and the "Overflow;" but I have grouped it all under one heading and called it "The Overflow."

The Overflow is an ideal spot for bird study, because within its bounds are found conditions suitable for nearly all classes of birds, as will be understood by the following brief description. Flowing along the northern boundary is the Huron River, whose south bank along the western half rises from a few to about ten or fifteen feet, as a bank upon which are found willows, elders and a few elm and maple trees. Toward the eastern limits the ridge gives way to a low flat field ending in a marshy area a few acres in extent. A ridge along the western portion, at one place, separates the river from a small marshy pond of some four or five acres in extent, which is surrounded by a thick growth of willows and elders. This growth also extends out from the shore and leaves but a small area of open water; a home for many water loving birds. A railroad and a wagon road bounds this pond on the south, while beyond the road, and occupying the larger half of the western part of the Overflow, is Blake's farm. This farm has along its western side, back from the road, a cultivated field, east of which is a small orchard and farm buildings. Then come two more fields, more or less rolling, back of which, on the western side, runs a long orchard of apple and peach trees, extending through to the southern boundary of the ter-

ritory. To the east of this orchard is a tract of woods, twenty-five or thirty acres, I should say, consisting of maple, ash, hickory and oak. In these woods is a brook with willows, elders, and thick brambles along its banks, while further on these give way to a bog a few acres in extent, covered by a thick growth of bushy cinquefoil. The eastern part of this woods is rolling, with many small pools, in the depressions between the ridges, surrounded by willows and button bushes.

To the east of the woods and bog, extending from the road to the south boundary, is a large tract of land devoted to pasture lots and cultivation, and containing about sixty or seventy acres. The entire eastern portion is the Overflow proper, a marsh covering about 100 acres, the western half of which can generally be traversed on foot, by using boots. Here is found a thick growth of willows and elders, with here and there a tamarack and patches of bushy cinquefoil. The eastern half can only be traversed by a boat and is covered by a growth of sedges and cat-tails, scattered clumps of willows, elders and button bushes. It is completely surrounded by a growth of willows and elders, but along the north side there is a tract of higher land running out into the marsh and covered by ash and a few elm and maple trees. Along the southern and part of the western side of the marsh is a ridge, at places bare and sandy, but for the most part covered with a growth of ash, poplar, maple and oak trees.

The Overflow proper has a broad outlet leading to the river, and in the spring when the river is high it backs up into the Overflow, thus forming a rather large sheet of water; a feeding ground for stray ducks and other water fowl.

From this brief description one can see the opportunities that this special territory offers for bird study; for one can find within a few minutes walk the habitats of many kinds of birds.

I will now attempt to classify the species observed in this territory according to the kind of conditions under which one is likely to find them; as those of the orchard, open woods, open fields, thickets, and the marshes and river.

It is rather difficult to draw hard and fast lines, for birds of one habitat are occasionally found in other conditions. Especially is this true during migration, because in the spring birds are not so closely confined to their usual haunts. This applies more particularly to our migratory woodland warblers, which, on account of the late leafing of the open woods, seem obliged to seek their food among the thickets of willows and elders along the marshes and streams, as these are well leaved upon the arrival of these birds and abound with insects and larvæ. Many birds are found at several different locations, and these are repeated for the benefit of those who chance to go to this territory, in order that they may know what species to expect, and under what conditions they occur.

I will first give under each locality the birds I have found to be resident, either the entire year or during the summer, and then the migrants and winter visitants.

BIRDS FOUND IN THE ORCHARDS.

Among the resident and summer resident birds found in the orchards are many of our common birds, such as the Bluebird, Robin, Chickadee, White-breasted Nuthatch, and oftentimes the House Wren, with its joyful song. The Warbling and Red-eyed Vireos often come into the orchard to feed, but I have never found them nesting there. Cedar Waxwings are common, both summer and winter, and I have often found their nests among the apple trees.

The Indigo Bunting is a common summer visitor and is often seen and heard; also the Song Sparrow, and while it is more a bird of the thicket, it often nests along the edge of the orchard and feeds among its trees. The Chipping Sparrow, American Goldfinch, Baltimore and Orchard Orioles and Kingbird all find suitable nesting conditions here, and their nests often contain the eggs of that ever-present intruder, the Cowbird. Nearly any day in the year one can find the Flicker, Downy and Hairy Woodpeckers patiently digging larvæ, or find their nesting sites in old tree stubs. The Blue Jay and Mourning Dove are also frequently found here the year round, and the Jay frequently nests among its trees. Less frequently the little Screech Owl is seen. On a few occasions I have here seen the Yellow-bellied Sapsucker, and flitting about among the trees, a Ruby-throated Humming Bird. I have often observed the Least Flycatcher come out from the nearby woods and feed in the orchard, and on June 6, 1901, I found a nest in an apple tree, which contained four slightly incubated eggs. In a tool house near the center of the orchard a pair of Phoebes each year find a home.

Among the migrants passing through in the spring are seen many warblers, and I have records, especially of those observed in the orchard, of the Nashville, Tennessee, Parula, Magnolia, and Yellow, the latter remaining here all summer. As to winter visitants I have frequently found the Junco and Golden-crowned Kinglet coming into the orchard, presumably to gather seeds and larvæ.

From such a large number of birds seen in one orchard, one can appreciate the vast amount of good done by the destruction each year of countless numbers of insects and larvæ.

BIRDS OF THE OPEN WOODS.

The birds I have observed in the open woods in the western part of the territory and about the Overflow proper will now be considered. Every fall and winter I have flushed a few Ruffed Grouse, but have never noticed them during the spring or summer months. Among the hawks and owls observed during the past four years in these woods, are the Red-tailed, Sharp-shinned, Cooper's and Pigeon Hawks, which occasionally come to rest or hunt, while the Red-shouldered and American Sparrow Hawk are often nesting here. In the spring of 1903 I found a nest, containing two young birds of the Great Horned Owl, in the woods on Blake's farm. The old birds are frequently found here and attention is often called to them by the clamor of a flock of tantalizing crows. Less frequently I have seen the Screech and Barred Owls; having shot one of the latter here on December 12, 1903. On January 16, 1902, I saw a

Snowy Owl in these woods; this is the only record I have of their being seen during my four years of observations.

Whenever visiting these woods one is almost sure to find the Downy and Hairy Woodpeckers, and White-breasted Nuthatch, and during the summer the Red-headed Woodpecker, Flicker, and occasionally the Yellow-bellied Sapsucker. On November 8, 1901, I saw a Red-bellied Woodpecker.

During the summer days I have frequently seen the Chimney Swifts soaring over these woods, and the Ruby-throated Hummingbird dart about among the trees. The Crested, Yellow-bellied and Least Flycatchers and Wood Pewee are summer residents in these woods; the last two I have found nesting, while the others have been seen during the breeding season and also probably nest here.

It is needless to say that the Cowbird is found here, for nearly always where there are other birds building you will find this impostor. From nearly every brush pile and from along the fence corners, one can frequently frighten a Towhee.

The Scarlet Tanager is common in summer, but I have never found it nesting in these woods. The Tamarack trees make a good feeding ground for the Cedar Waxwings, which are found here the year round, and they often nest in these trees. On May 13, 1901, I stood at one place in these woods and secured for the University Museum specimens of Red-eyed, Warbling, Yellow-throated and Blue-headed Vireos. The same afternoon I also saw here a Philadelphia Vireo. The Red-eyed Vireo nests in the low saplings, and the Warbling Vireo in the higher trees, but I have never found any of the others nesting here.

No matter how cold or stormy the day, one always can find the little Chickadee. Among the summer resident warblers found in the woods I have observed the Cerulean Warbler, Ovenbird and American Redstart, all of which I have found nesting. I know of no place where I have seen more Blue-gray Gnatcatchers than here, and every spring I have found from one to a half dozen of their nests. The Wood Thrush is common here and nests among the trees, and occasionally a Wilson's Thrush is seen.

The larger portion of migrant birds seen here during spring and fall are warblers, and I have observed the following nearly every spring in these woods: Black and White, Nashville, Tennessee, Black-throated Blue, Myrtle, Magnolia, Chestnut-sided, Bay-breasted, Black-throated Green, Pine, Palm, Prairie and Canadian. These are only here for a few days, a week at the most, so that one must be in the field or they will be missed. The Golden-crowned and Ruby-crowned Kinglets are often seen spring and fall; the former quite frequently remaining all winter. Occasionally a Red-breasted Nuthatch is seen, and often during migration the Hermit and Olive-backed Thrushes.

During the winter Brown Creepers can be found here nearly every day. In the winter of 1904-05 two Tufted Titmice spent the entire winter in these woods and would be seen on each trip.

BIRDS OF THE OPEN FIELD.

The birds found in open fields, such as pasture and cultivated lots, are relatively few in number with regard to species, but very numerous as to individuals.

In the pasture lots and hay fields, we of course find the Meadowlark, Bobolink, Vesper Sparrow, Field Sparrow and Prairie Horned Lark, all of which are summer residents and nest here.

Very often I have seen the Bobwhite in these fields, frequently sitting in early morning on the fences, whistling. Occasionally the Mourning Doves come into the pasture lots to feed, and I have seen them gather here in small flocks of from about eight to a dozen.

Nearly every year I have seen a few Grasshopper Sparrows, particularly in those fields which had many weeds. I think the Barn Swallow should be mentioned among the birds of the open fields, for they are ever skimming over them in search of insects. The Killdeer often comes into the pasture lots and seeks a nesting site in the corn fields, where it builds its nest at the foot of the hills of corn. In the open field bordering the river, on June 6, 1902, I found a nest of the Nighthawk with two fresh eggs.

Each year during the spring migrations I have seen a few Lark Sparrows in these fields, but never more than three or four during a season. In the winter the Snowflake occasionally visits the fields, as during the winters of 1902-03 and 1903-04. They often remind one of the drifting snow as they fly from one feeding ground to another; but they do not seem to visit us every winter.

BIRDS OF THE THICKET.

Under this heading I have placed the birds that I have seen in the elder and willow thickets on the north side of Blake's woods, and around the Overflow proper; most of them having been seen in the latter place. On October 12, 1903, I saw a Short-eared Owl in the willows at Blake's woods; it seemed to be dozing, for I came quite close to it before it flew away into the woods.

About the first of June each year I have seen a few Yellow-billed Cuckoos, and less frequently a Black-billed Cuckoo in the thickets about the Overflow; and on a few occasions I have started Night-hawks from here. More typical, however, of the thickets are the Blue Jay, American Goldfinch, Song Sparrow, Towhee, Rose-breasted Grosbeak, Indigo Bunting, Yellow Warbler, Maryland Yellow-throat, American Redstart, Cat-bird, Brown Thrasher and Chickadee, all of which find nesting places here and can often be seen. During the past few summers a Cardinal or two have been seen in these thickets, but they perhaps came only to feed and nested closer to the city, where they were more frequently seen.

Here is the best place to study the spring migration of the sparrows and warblers. Among the former there are always large numbers of the White-throated, White-crowned and Fox Sparrows, and very rarely a Lincoln's Sparrow. I think there are more of the latter here every year than are reported, because they are easily mistaken at a distance for other sparrows, and furthermore, are very quiet and keep close to the ground.

The warblers seen in these thickets include all the varieties mentioned among those observed in the open woods, and besides the Golden-winged, Parula, Cape May, Black-poll, Wilson's and Mourning Warblers. On May 6, 1905, Mr. N. A. Wood and I saw a male of Kirtland's Warbler

in the thicket at the Overflow. Besides these I have occasionally seen the Water Thrush and Louisiana Water Thrush in the willows about the Overflow.

During migration we may always expect to see the Golden-crowned and Ruby-crowned Kinglets, and Wilson's and Hermit Thrushes, while among the winter visitors each year, the Purple Finch, Tree Sparrow, Junco, and occasionally a Redpool, seek shelter and food in these thickets.

BIRDS OF THE MARSHES AND RIVER.

There are several species of birds that are found all summer in the marshes and along the river, and many more which occur there only during the migration periods. Of the summer residents the Pied-billed Grebe and American Coot are the only swimmers that are found in the marsh. The American and Least Bittern are quite common, the former apparently more so than the latter; its "pumping" being frequently heard. The Great Blue Heron is often seen along the river, but does not nest in this particular territory; the Green Heron does however, and their nests may be found each year in the small marshy pond on the north side of the railroad. The Virginia and Sora Rails are seen in the marsh each spring and probably nest, but I have never run across them except during the spring. The bogs also furnish a good feeding ground for the American Woodcock, Spotted Sandpiper and Killdeer, but they usually nest on higher and drier ground. Every year I have found a nest of the Marsh Hawk among the bushy cinquefoil, both at Blake's and at the Overflow proper, and on March 30, 1904, I found a nest of five eggs of the American Long-eared Owl at Blake's.

The Belted Kingfisher is frequently heard and seen along the river, but it nests on the opposite side of the river in the sand banks. The Red-winged Blackbird and Cowbird are very common, and in the spring and fall, large flocks of Bronzed Grackles and Rusty Blackbirds and also of Bobolinks are seen here.

The Swamp Sparrows are quite common about the Overflow, but I have never found them nesting. Of the swallows frequently seen skimming over the river and marshes are the Tree and Bank, and occasionally a Purple Martin or a Cliff Swallow. The Maryland Yellow-throats are very common and can be heard singing in the marsh and along its edges all summer. I have frequently seen the Long-billed Marsh Wren at the Overflow, and on June 2, 1903, a boy brought in a Short-billed Marsh Wren that he had killed there, but I never saw one myself.

Each spring before the ice is out of the lakes many Loons gather along the river, and especially during the spring of 1904, one could generally find from five to a dozen in front of the Overflow, feeding and swimming about; several were killed by boys. A few American Herring Gulls come up the river each spring, but are only here for a few days, and I have seen the American and Hooded Mergansers, Mallards, Green-winged Teal, Wood Ducks, Red Head and the American Golden-eye, feeding here during the spring migration. During the winter of 1903-4 a flock of fifteen American Mergansers tried to winter on the river, much to their disaster, for by spring the last one had been shot. Flocks of the Canada Goose fly over each spring and fall, but I have never seen them settle. During migration, Wilson's and the Solitary

Sandpiper are occasionally seen, and during the spring of 1904 many Ospreys were seen along the river and several were shot.

Of the migratory warblers that seem to prefer the marshy lands I have seen the Golden-winged and Mourning Warblers, Yellow-breasted Chat, Water Thrush and Louisiana Water Thrush at the Overflow. The Winter Wren is often seen each spring and fall, particularly in the bushy cinquefoil bog on Blake's farm.

The preceding records outline my observations for four years on the birds seen at the Overflow, and I hope that this will serve as a working basis for local students, so that they may be able to add many more observations to them, and that it may be of assistance to others in preparing lists of other localities favorable for bird study.

Below is appended an annotated list of the birds seen, with such data as is deemed necessary.

BIRDS OF THE "OVERFLOW"

1. *Podilymbus podiceps.* Pied-billed Grebe.—A few nest at the Overflow every summer. They arrive about the last of April and remain until October.
2. *Gavia imber.* Loon.—Frequently seen on the river in the spring before the ice is out of the lakes. I have a record of eight being seen April 16, 1904.
3. *Larus argentatus.* Herring Gull.—A few come up the river to feed each spring. The earliest record I have is February 28, 1904.
4. *Merganser americanus.* American Merganser.—Common along the the river during migration. One flock of fifteen spent the winter here during 1903-1904.
5. *Lophodytes cucullatus.* Hooded Merganser.—A few seen along the river and in the marsh during the fall. I shot a male at the Overflow, October 12, 1902.
6. *Anas bochas.* Mallard.—A few during the migration season settle in the marsh to feed. A flock of five was seen here April 16, 1903.
7. *Anas carolinensis.* Green-winged Teal.—I saw two that were shot here on October 10, 1901.
8. *Aix sponsa.* Wood Duck.—I have seen but one here and that was on October 20, 1902.
9. *Aythya americana.* Redhead.—Two Redheads were seen with a flock of Mallards on the river on October 16, 1902.
10. *Clangula clangula americana.* American Golden-eye.—Two were seen on the river March 5, 1904.
11. *Branta canadensis.* Canada Goose.—Large flocks are seen here during migration, following the course of the river. A flock of forty-nine was seen March 29, 1904.
12. *Botaurus lentiginosus.* American Bittern.—Common summer resident at the marsh. The earliest record I have is April 6, 1903.
13. *Ardetta exilis.* Least Bittern.—A few seen each year and they probably nest in the marsh. I have records for May 17, 1902, June 2, 1903, May 21, 1904.
14. *Ardea herodias.* Great Blue Heron.—A few come to feed in the marsh and along the river. I have records for first arrivals May 2, 1903, April 22, 1904, April 27, 1905.
15. *Ardea virescens.* Green Heron.—A pair nest in the marsh between the railroad and river every year. I have records on May 17, 1902, May 13, 1903, May 13, 1904, May 24, 1905.
16. *Rallus virginianus.* Virginia Rail.—Frequently seen during migration periods in spring, June 3, 1903, May 13, 1904, May 21, 1905.
17. *Porzana carolina.* Sora.—A few seen each year in the marsh. The earliest record I have is May 6, 1903.
18. *Fulica americana.* American Coot.—Common in the marsh all summer. Spring records April 22, 1903, May 2, 1904, May 17, 1905.
19. *Philohela minor.* American Woodcock.—Frequently flushed from the thickets around the marsh; March 19, 1903, March 30, 1904, March 23, 1905.

20. *Gallinago delicata.* Wilson's Snipe.—A few are occasionally seen during spring migration. Records, on April 21, 1902, May 1, 1904.

21. *Totanus solitarius.* Solitary Sandpiper.—Occasionally seen during migration, April 29, 1902, May 2, 1903, May 7, 1905.

22. *Actitis macularia.* Spotted Sandpiper.—Very common all summer, arriving the last of April and staying until the last of September or first of October.

23. *Oxyechus vociferus.* Killdeer.—Very common, feeding in the marsh and along the river, and nesting in the corn fields.

24. *Colinus virginianus.* Bob-white.—Common the year round in the fields and edges of the woods.

25. *Bonasa umbellus.* Ruffed Grouse.—A few occasionally flushed during the fall in the woods.

26. *Zeniadura macroura.* Mourning Dove.—Very common, some remaining all winter. Nests in the orchards.

27. *Circus hudsonius.* Marsh Hawk.—Very common summer resident. Nesting at Blake's and in the Overflow. Nests found May 30, 1902, May 18, 1903, May 22, 1904.

28. *Accipiter velox.* Sharp-shinned Hawk.—Occasionally seen in the woods. Records on May 22, 1903, June 1, 1905.

29. *Accipiter cooperii.* Cooper's Hawk.—Occasionally seen nesting in the woods. Records on April 16, 1902, May 2, 1903.

30. *Buteo borealis.* Red-tailed Hawk.—Seen but once in the woods at Blake's on May 12, 1903.

31. *Buteo lineatus.* Red-shouldered Hawk.—Common, occasionally nesting in Blake's. Nest found May 3, 1903.

32. *Falco columbarius.* Pigeon Hawk.—A few seen during migration each year, May 10, 1902, April 28, 1904.

33. *Falco sparverius.* American Sparrow Hawk.—Commonly seen in woods where it nests. Often seen soaring over the fields.

34. *Pandion haliaetus carolinensis.* American Osprey.—A few come up the river each spring. Two were shot at the Overflow April 9, 1904.

35. *Asio wilsonianus.* American Long-eared Owl.—Not common. Nest and five eggs found in the bog at Blake's on March 30, 1904.

36. *Asio accipitrinus.* Short-eared Owl.—Not common. One seen in a willow thicket at Blake's on October 12, 1903.

37. *Syrnium varium.* Barred Owl.—But one seen here during four years, this one I shot in Blake's woods on December 12, 1903.

38. *Megascops asio.* Screech Owl.—Seen occasionally in the orchards, May 15, 1902, May 2, 1904.

39. *Bubo virginianus.* Great Horned Owl.—A few pair spend the year in Blake's woods and about the Overflow. On April 3, 1903, I found a nest with two half grown young in Blake's woods.

40. *Nyctea nyctea.* Snowy Owl.—An occasional winter visitor. One seen in Blake's woods on January 16, 1902.

41. *Coccyzus americanus.* Yellow-billed Cuckoo.—A few seen in the thickets about the marsh each year, May 6, 1904, May 10, 1903, May 19, 1905.

42. *Coccyzus erythrophthalmus.* Black-billed Cuckoo.—I have but one record of seeing this bird at the Overflow on May 14, 1903.

43. *Ceryle alcyon.* Belted Kingfisher.—Common at the Overflow and along the river, nesting on the north side of the river.

44. *Dryobates villosus.* Hairy Woodpecker.—Common the year round in the orchards and woods, nesting in both places.

45. *Dryobates pubescens medianus.*—Downy Woodpecker.—Common the year round in orchards and woods, nesting in both places.

46. *Sphyrapicus varius.* Yellow-bellied Sapsucker.—Common summer resident. I have spring records on April 7, 1903, April 17, 1904, April 15, 1905.

47. *Melanerpes erythrocephalus.* Red-headed Woodpecker.—Very common, a few spend mild winters here.

48. *Melanerpes carolinus.* Red-bellied Woodpecker.—Not common. One seen in Blake's woods on November 8, 1904.

49. *Colaptes auratus luteus.* Northern Flicker.—Very common, a few spending the winter here.

50. *Chordeiles virginianus.* Nighthawk.—Not common at the Overflow. A few

have been frightened from the thickets, and on June 5, 1902, I found a nest with two fresh eggs in an open field bordering the river.

51. *Chaetura pelagica.* Chimney Swift.—Common summer resident, nesting about the farm buildings. Spring arrivals on April 19, 1903, April 23, 1904, April 20, 1905.

52. *Trochilus colubris.* Ruby-throated Hummingbird.—A few seen each year in the woods and orchards. First spring records on May 15, 1903, May 13, 1904, May 17, 1905.

53. *Tyrannus tyrannus.* Kingbird.—Very common summer resident, nesting in the orchards. Spring arrivals on May 6, 1902, May 1, 1903, May 7, 1904, May 9, 1905.

54. *Myiarchus crinitus.* Crested Flycatcher.—A few each year as summer residents, nesting in the woods, May 7, 1902, May 1, 1903, May 4, 1905.

55. *Sayornis phoebe.* Phoebe.—Common summer resident, nesting each year in a tool house in the orchard. Spring arrivals, March 20, 1902, March 18, 1903, March 25, 1904, March 16, 1905.

56. *Nuttallornis borealis.* Olive-sided Flycatcher.—A few seen each year in the woods. May 1, 1903, May 14, 1904, May 18, 1905.

57. *Contopus virens.* Wood Pewee.—Common summer resident in the orchards and woods, arriving May 14, 1903, May 7, 1904, May 12, 1905.

58. *Empidonax flaviventris.* Yellow-bellied Flycatcher.—Frequently seen and probably nests in the woods; spring arrivals, May 17, 1902, May 13, 1903, May 14, 1905.

59. *Empidonax minimus.* Least Flycatcher.—Very common summer resident; nesting in the orchards and woods; arriving May 1, 1902, April 30, 1903, May 2, 1904, May 4, 1905.

60. *Otocoris alpestris praticola.* Prairie Horned Lark.—Common summer resident, a few remaining all winter and nesting early in March in the open fields.

61. *Cyanocitta cristata.* Blue Jay.—Very common resident, nesting in the orchards and thickets.

62. *Corvus brachyrhynchos.* American Crow.—Very common; a few remaining all winter.

63. *Dolichonyx oryzivorus.* Bobolink.—Very common summer resident, nesting in the meadows and along fences; spring arrivals April 27, 1902, April 30, 1903, April 24, 1904, April 29, 1905.

64. *Molothrus ater.* Cowbird.—Very common all summer, arriving early in the spring; March 20, 1902, March 22, 1903, March 28, 1904, March 21, 1905.

65. *Agelaius phoeniceus.* Red-winged Blackbird.—Very common summer resident, nesting in the marshes; spring arrivals on March 11, 1902, March 9, 1903, March 12, 1904, March 17, 1905.

66. *Sturnella magna.* Meadowlark.—Very common summer resident, nesting in the meadows; spring arrivals on March 10, 1902, March 8, 1903, March 2, 1904, March 16, 1905.

67. *Icterus spurius.* Orchard Oriole.—Common summer resident, nesting in the orchards; spring arrivals on April 22, 1902, April 25, 1903, April 21, 1904, April 29, 1905.

68. *Icterus galbula.* Baltimore Oriole.—Very common summer resident, nesting in the orchards; spring arrivals on April 22, 1902, April 25, 1903, April 21, 1904, April 29, 1905.

69. *Ephagus carolinus.* Rusty Blackbird.—Commonly seen in flocks during the spring, in the woods and marshes, March 7, 1902, March 6, 1903, March 2, 1904.

70. *Quiscalus quiscula aeneus.* Bronzed Grackle.—Very common summer resident, nesting in trees along the river; spring arrivals on March 5, 1902, March 9, 1903, March 2, 1904, March 17, 1905.

71. *Carpodacus purpureus.* Purple Finch.—Common winter resident, arriving in October and remaining until the last of March.

72. *Acanthis linaria.* Redpoll.—Not common; I have but two records, November 3, 1902, March 2, 1904.

73. *Astragalinus tristis.* American Goldfinch.—Very common resident, nesting in the thickets and orchards, and gathering in large flocks during winter.

74. *Passerina nivalis.* Snowflake.—Not regular winter visitors. Large flocks were frequently seen during the winters of 1902-3 and 1903-4.

75. *Poocaetes gramineus.* Vesper Sparrow.—Very common summer resident,

nesting along the woods and in the open fields and orchards; arrivals on March 14, 1902, March 21, 1903, March 24, 1904, March 18, 1905.

76. *Coturniculus savannarum passerinus.* Grasshopper Sparrow.—Rather common summer resident, nesting in meadows, preferably those with weeds; spring arrivals on May 8, 1903, May 7, 1904, May 11, 1905.

77. *Chondestes grammacus.* Lark Sparrow.—A few seen generally at migration time in the open fields; records on May 3, 1903, May 7, 1905.

78. *Zonotrichia leucophrys.* White-crowned Sparrow.—Rather common during spring and fall migration in the thickets; spring arrivals, April 23, 1902, April 28, 1903, April 23, 1904, April 29, 1905.

79. *Zonotrichia albicollis.* White-throated Sparrow.—Very common during spring and fall migrations in the thickets; spring arrivals on April 20, 1902, April 19, 1903, April 24, 1904, April 26, 1905.

80. *Spizella monticola.* Tree Sparrow.—Very common winter resident, arriving the middle of October and remaining until about the first of April.

81. *Spizella socialis.* Chipping Sparrow.—Very common summer resident, nesting in the orchards and about the farm house; spring arrivals on April 2, 1902, March 21, 1903, March 22, 1904, March 27, 1905.

82. *Spizella pusilla.* Field Sparrow.—Very common summer resident, nesting in the open fields and at the edge of the thickets; spring arrivals on March 26, 1902, March 22, 1903, March 29, 1904, March 26, 1905.

83. *Junco hyemalis.* Slate-colored Junco.—Very common winter resident, arriving in October and remaining until about the first of April.

84. *Melospiza cinerea melodia.* Song Sparrow.—Very common resident, nesting in the open fields, thickets and marshes.

85. *Melospiza lincolnii.* Lincoln's Sparrow.—Only occasionally seen in the thickets during migration. I have but two records, May 9, 1903, May 12, 1904.

86. *Melospiza georgiana.* Swamp Sparrow.—Very common summer resident in the marshes; arriving on March 29, 1902, April 3, 1903, April 1, 1904, April 16, 1905.

87. *Passerella iliaca.* Fox Sparrow.—Common migrant in the thickets, spring and fall; spring arrivals, March 22, 1903, March 25, 1904, March 18, 1905.

88. *Pipilo erythrophthalmus.* Towhee.—Very common summer resident, nesting in the woods and thickets; spring arrivals on March 18, 1902, March 14, 1903, March 25, 1904, March 18, 1905.

89. *Cardinalis cardinalis.* Cardinal.—A few cardinals are occasionally seen feeding in the thickets during the summer; not common.

90. *Zamelodia ludoviciana.* Rose-breasted Grosbeak.—Very common summer resident in the thickets, arriving May 1, 1902, April 30, 1903, May 4, 1904, May 3, 1905.

91. *Cyanospiza cyanea.* Indigo Bunting.—A common summer resident, nesting in the thickets and briers about the orchards; spring arrivals May 9, 1902, May 10, 1903, May 7, 1904, May 12, 1905.

92. *Piranga erythromelas.* Scarlet Tanager.—Common summer resident, nesting in the open woods; spring arrivals, May 10, 1902, May 7, 1903, May 7, 1904, May 11, 1905.

93. *Progne subis.* Purple Martin.—A few seen occasionally skimming over the river and marsh; records, April 3, 1903, April 17, 1904.

94. *Petrochelidon lunifrons.* Cliff Swallow.—A few seen along the river and marshes each spring and summer. The only record I have in my notes, however, is April 24, 1904.

95. *Hirundo erythrogastra.* Barn Swallow.—Several nest about the farm buildings each year and are seen flying over the fields; spring arrivals, April 15, 1902, April 16, 1903, April 24, 1904, April 20, 1905.

96. *Tachycineta bicolor.* Tree Swallow.—Very common summer resident, nesting along the river and feeding over the fields and marshes; spring arrivals, April 15, 1902, April 13, 1903, April 17, 1904, April 19, 1905.

97. *Riparia riparia.* Bank Swallow.—A few seen along the river each spring, but do not nest at the Overflow; spring arrivals, April 14, 1902, April 17, 1903, April 20, 1905.

98. *Ampelis cedrorum.* Cedar Waxwing.—Common resident in the orchards and tamaracks in the woods, nesting in both places.

99. *Vireo olivaceus.* Red-eyed Vireo.—Common summer resident, nesting in

the open woods; spring arrivals, May 4, 1902, May 3, 1903, May 7, 1904, May 9, 1905.

100. *Vireo philadelphicus.* Philadelphia Vireo.—Occasionally seen during migration time; one record, May 13, 1904.

101. *Vireo gilvus.* Warbling Vireo.—Very common summer resident, nesting in the orchards and open woods; spring arrivals, May 3, 1902, April 29, 1903, April 21, 1904, April 26, 1905.

102. *Vireo flavifrons.* Yellow-throated Vireo.—Common summer resident, nesting in the open woods; spring arrivals, May 2, 1902, May 3, 1903, April 26, 1904, May 1, 1905.

103. *Vireo solitarius.* Blue-headed Vireo.—Not common. Occasionally seen during migration; records, May 10, 1903, May 7, 1904.

104. *Mniotilta varia.* Black and White Warbler.—Very common during migration in the woods, orchards and thickets; arrivals April 26, 1902, April 16, 1903, April 24, 1904, April 28, 1905.

105. *Helminthophila chrysoptera.* Golden-winged Warbler.—Not common. Occasionally seen during spring migration in the thickets about the marshes; records on May 3, 1903, May 12, 1904, May 15, 1905.

106. *Helminthophila rubricapilla.* Nashville Warbler.—Common during migration in the orchards, woods and thickets; records, May 12, 1902, May 9, 1903, May 7, 1904, May 11, 1905.

107. *Helminthophila peregrina.* Tennessee Warbler.—Not common, occasionally seen during migration in the orchards and woods; records, May 9, 1903, May 12, 1905.

108. *Compsothlypis americana usnea.* Northern Parula Warbler.—Not common; a few seen occasionally during spring migration; records on May 7, 1903, May 7, 1904, May 9, 1905.

109. *Dendroica tigrina.* Cape May Warbler.—Not common, only occasionally seen during migration in the thickets and woods; one record, May 14, 1903.

110. *Dendrioca aestiva.* Yellow Warbler.—Very common summer resident, nesting in the thickets; spring arrivals, April 26, 1902, April 28, 1903, April 24, 1904, April 29, 1905.

111. *Dendroica caerulescens.* Black-throated Blue Warbler.—Rather common during spring migration in orchards, woods and thickets; May 10, 1902, May 8, 1903, May 7, 1904, May 8, 1905.

112. *Dendroica coronata.* Myrtle Warbler.—Very common during migrations in the woods and thickets; spring arrivals, May 2, 1902, April 28, 1903, April 24, 1904, April 29, 1905.

113. *Dendroica maculosa.* Magnolia Warbler.—Common during spring migrations in orchards, woods and thickets; spring arrivals, May 10, 1902, May 13, 1903, May 7, 1904, May 12, 1905.

114. *Dendroica caerulea.* Cerulean Warbler.—Not common, a few nest in the woods each year; spring arrivals, May 12, 1903, May 15, 1904.

115. *Dendroica pensylvanica.* Chestnut-sided Warbler.—Rather common during migrations in the woods, orchards and thickets; spring arrivals, May 12, 1902, May 10, 1903, May 7, 1904, May 12, 1905.

116. *Dendroica castanea.* Bay-breasted Warbler.—Several seen each spring in the woods and thickets; spring arrivals, May 14, 1902, May 10, 1903, May 13, 1904, May 15, 1905.

117. *Dendroica striata.* Black-poll Warbler.—Not common, a few occasionally seen in the thickets during spring migrations; records, May 17, 1903, May 13, 1904.

118. *Dendroica virens.* Black-throated Green Warbler.—Very common during migrations in woods and thickets; spring arrivals, May 3, 1902, May 1, 1903, May 7, 1904, May 9, 1905.

119. *Dendroica kirtlandi.* Kirtland's Warbler.—Very rare, only one record having been made by Mr. N. A. Wood and myself, May 6, 1905, in the thicket around the Overflow proper.

120. *Dendroica virgorsii.* Pine Warbler.—Occasionally seen during spring migration in the orchards and thickets; record, May 11, 1904.

121. *Dendroica palmarum.* Palm Warbler.—Occasionally seen in the orchards, woods and thickets during migration; records, May 2, 1903, May 12, 1904.

122. *Dendroica discolor.* Prairie Warbler.—Not common, a few occasionally seen during migrations in the thickets and woods; record, May 9, 1903.

123. *Seiurus aurocapillus.* Oven-bird.—Very common summer resident, nesting in the open woods; arrivals on May 2, 1902, May 3, 1903, May 2, 1904, May 5, 1905.

124. *Seiurus noveboracensis.* Water Thrush.—Not common, a few occasionally seen in the thickets about the marshes during migrations; records on May 6, 1903, May 8, 1904.

125. *Seiurus motacilla.* Louisiana Water-Thrush.—But one record of one being seen on the edge of the marsh, May 11, 1902.

126. *Geothlypis philadelphia.* Mourning Warbler.—Rather common during migrations, especially in the fallen brush about the marshes; records, May 12, 1903, May 10, 1904, May 14, 1905.

127. *Geothlypis trichas brachidactyla.* Northern Yellow-throat.—Common summer resident, about the marshes and bogs; arrivals May 9, 1902, May 7, 1903, May 13, 1904, May 12, 1905.

128. *Icteria virens.* Yellow-breasted Chat.—Not common; but one record, having been seen in the marsh on May 15, 1902.

129. *Wilsonia pusilla* Wilson's Warbler.—Not common, a few occasionally seen during migrations; records May 23, 1903, May 10, 1904, May 17, 1905.

130. *Wilsonia canadensis.* Canadian Warbler.—Not common, a few seen occasionally during migrations in the thickets and woods; records, May 14, 1903, May 10, 1904, May 16, 1905.

131. *Setophaga ruticilla.* American Redstart.—Very common summer resident, nesting in the woods and thickets. Spring arrivals, May 3, 1902, May 5, 1903, May 4, 1904, May 6, 1905.

132. *Galeoscoptes carolinensis.* Catbird.—Very common summer resident, nesting in the thickets; arrivals, April 26, 1902, April 29, 1903, April 24, 1904, April 27, 1905.

133. *Toxostoma rufum.* Brown Thrasher.—Very common summer resident, nesting in the thickets; arrivals, March 20, 1902, March 18, 1903, April 23, 1904, April 5, 1905.

134. *Troglodytes aedon.* House Wren.—Common summer resident, nesting in the orchards and about the farm buildings; arrivals, April 20, 1902, April 23, 1903, April 24, 1904, April 25, 1905.

135. *Olbiorchilus hiemalis.* Winter Wren.—A few seen each year in the brush about the marshes and bogs during migrations; arrivals, April 16, 1902, April 9, 1903, April 18, 1904, April 26, 1905.

136. *Cistothorus stellaris.* Short-billed Marsh Wren.—One record of a bird brought to me on June 2, 1903, which was shot at the Overflow.

137. *Telmatodytes palustris.* Long-billed Marsh Wren.—A rather uncommon summer resident, nesting in the marsh; records, May 15, 1903; nesting, May 12, 1904.

138. *Certhia familiaris americanus.* Brown Creeper.—Common winter resident in the woods and orchards, arriving in October and remaining until the first of April.

139. *Sitta carolinensis.* White-breasted Nuthatch.—Common resident, nesting in the orchards and open woods.

140. *Sitta canadensis.* Red-breasted Nuthatch.—Not common. A few occasionally seen during migrations; records, April 25, 1904, October 8, 1904, April 28, 1905.

141. *Baeolophus bicolor.* Tufted Titmouse.—During the winter of 1903-1904, a pair of these birds remained in Blake's woods.

142. *Parus atricapillus.* Chickadee.—Very common resident, nesting in the thickets, orchards and woods.

143. *Regulus satrapa.* Golden-crowned Kinglet.—Common during migrations in the thickets, orchards and woods; arrivals, April 2, 1902, March 21, 1903, March 30, 1904, April 3, 1905.

144. *Regulus calendula.* Ruby-crowned Kinglet.—Not common. A few seen during migrations; records, April 12, 1903, and April 23, 1904.

145. *Polioptila caerulea.* Blue-gray Gnatcatcher.—Common summer resident, nesting in the open woods; arrivals, April 21, 1902, April 19, 1903, April 25, 1904, April 23, 1905.

146. *Hylocichla mustelina.* Wood Thrush.—Common summer resident, nesting in the open woods; arrivals, May 3, 1902, May 7, 1903, May 4, 1904, May 8, 1905.

147. *Hylocichla fuscescens.* Wilson's Thrush.—Common during migrations in the thickets and open woods; arrivals, May 6, 1902, May 1, 1903, April 17, 1904, April 26, 1905.

148. *Hylocichla ustulata swainsonii.* Olive-backed Thrush.—A few seen during migrations in the thickets and woods; records, May 12, 1903, May 18, 1904.

149. *Hylocichla guttata pallasii.* Hermit Thrush.—Common in the thickets and woods during migration; arrivals, April 12, 1902, April 5, 1903, April 7, 1904, April 5, 1905.

150. *Merula migratoria.* American Robin.—Abundant summer resident, nesting in the orchards and about the farm buildings; arrivals, February 28, 1902, February 28, 1903, March 2, 1904, March 1, 1905.

151. *Sialia sialis.* Bluebird.—Abundant summer resident, nesting in the orchards; arrivals, March 8, 1902, March 3, 1903, March 5, 1905.

NOTES ON THE FISH OF HILLSDALE COUNTY, MICHIGAN.

T. L. HANKINSON.

The notes given in this paper are based chiefly upon some fishes taken during two visits which I made to Hillsdale County, Michigan. One visit was from August 28 to September 11, 1900, and one from August 28 to September 4, 1902. In this work I was making no attempt to get a representative collection of the fish of the region, but I was simply looking for forms new to me. No pretentions are thus made for this paper to give a list, which approaches completeness, of the fish in the vicinity of Hillsdale. Most of the specimens collected were taken to Cornell University, where I identified them with some assistance from Mr. H. D Reed, under whose direction I was then doing special work in ichthyology. During some ten years of residence in Hillsdale, prior to the time when the first of the above-mentioned collections was made, I took many fishing trips in the region, and although my aims were not of a scientific nature, I obtained some general information about the fish of the region; and such of the facts so obtained, that I think may have some value, are here recorded.

The collections referred to were made from the following named bodies of water: Bawbeese lake, King lake, Stock's mill pond, outlet of King lake, Beebe creek, a small pasture brook in the south part of Hillsdale, and a stream near Allen. Only a small part of any one of these regions was fished. A dip net and a small eight-foot minnow seine was the collecting apparatus used in the streams. In the lakes, the hook and line method was the only one employed, except at Bawbeese lake, where some dip net and minnow seine fishing was done in shallow water near shore. A brief description of each of the more important localities, mentioned above, is here given.

Bawbeese lake. This is located about one and one-half miles southeast of Hillsdale. It is a system of about five lakes. The north one is the largest, and is the one in which most of my lake fishing was done. It is a little over a mile long and about three-quarters of a mile wide. It has many shoals, chiefly on its east side, which have for the most part, hard, sandy bottoms. Its greatest depth is said to be about ninety feet. The water is clear and pure, and is used to supply the city of Hillsdale. The outlet leaves the lake near its north end, and flows in a northwesterly direction through the center of the city of Hillsdale and on toward Jonesville. Residents of Hillsdale tell me that this stream is a tributary of the St. Joseph river which enters Lake Michigan.

Stock's mill pond. This pond was formed by damming the outlet of Bawbeese lake. It is located in the southeast part of Hillsdale near the fair grounds. It is about one-half mile in length, rather shallow, with a depth perhaps not greater than fifteen or twenty feet, and in the summer it has an abundance of aquatic vegetation.

King lake. This is a small lake, about a mile south of the corporation line of Hillsdale. It is probably one-half mile in length by about one-quarter mile in width. Its shores are for the most part marshy. A narrow and distinct shoal with a thick growth of rushes runs almost entirely around it. The lake is said to be very deep. Its outlet is a small brook that flows for some one and one-half miles to join the outlet of Bawbeese lake, just above the mill pond.

Beebe creek. This is a large creek about a mile north of Hillsdale. It flows in a westerly direction, and is probably part of the St. Joseph system.

The names of the species given in this paper are those used by Jordan and Evermann in their "Fishes of North and Middle America."

The measurements of the length were taken, in each case, from the tip of the snout to the tip of the caudal fin. These were made in centimeters. Estimates of dimensions are given in feet and inches.

LIST OF FISH WITH NOTES.

Lepisosteus osseus (Linnaeus). Long-nosed Gar.—One small specimen about six inches long was taken from shallow water near the east shore of Bawbeese Lake.

I once saw a large gar pike, that was probably this species, while I was skating on clear ice over the deepest part of Bawbeese Lake. The fish was about three feet in length, and was but a foot or so beneath the ice. I stood and watched the fish for a number of seconds, till it swam slowly away. At Hemlock Lake, west of Bankers, I once saw many gar pike together, swimming just beneath the surface of the deep water of a shady cove.

Amia calva Linnaeus. Dogfish.—One was taken by hook and line from Bawbeese Lake, August 28, 1902. It was thirty-eight cm. long, and on dissection, was found to have in its alimentary canal a head of a blunt-nose minnow, *Pimephales notatus*, and a black bass, *Micropterus salmoides*, five cm. long.

I have caught many of these fish by hook and line in various lakes in Hillsdale county, and it is undoubtedly very common in the region. I have found them at night in the outlet of King Lake in early April at times when suckers were running in the creek.

Ameiurus natalis (LeSueur.) Yellow Cat.—Three were taken by dip net in the outlet of King Lake. These were small specimens about of a size, averaging six cm. in length. Twenty were caught in Bawbeese Lake by hook and line on September 6, 1900. They averaged probably between nine and ten inches in length.

The species is abundant about Hillsdale, and is commonly known as the "bullhead." I have seldom failed to catch them when fishing at night over muddy bottom. I caught a number one winter by leaving lines over night through holes in the ice at Stock's mill pond.

Catostomus commersonii (Lacépède). Common Sucker.—Nine small specimens, five and one-half to sixteen cm. long were taken from the outlet of King Lake, near the lake. Three, six and three-fourths to eight cm. long were caught at Beebe creek. One measuring seven cm. long was taken in a small pasture stream west of Reading avenue, in the south part of Hillsdale.

Campostoma anomalum (Rafinesque). Stone-roller.—This was found to be a very common minnow in nearly all of the streams where I fished. Many were taken, the largest being sixteen cm. long, and was from Beebe creek.

Pimephales notatus (Rafinesque). Blunt-nosed Minnow.—The minnow was found to be very abundant in Bawbeese Lake, where it was seen in large schools in shallow water. Not many were found in streams. One was taken from the outlet of King Lake and six from Beebe creek.

Semotilus atromaculatus (Mitchill). Horned Dace.—This fish was found abundant in all streams where fishing was done.

Abramis chrysoleucas (Mitchill). Golden Shiner.—Seven were taken in the small pasture stream west of Reading avenue. These were small, six to eleven cm. long. The stream where these were caught was from one to two feet wide and almost concealed by high grass. I have occasionally taken large examples of the species, ten inches or so in length, by hook and line, from Stock's mill pond.

Notropis heterodon (Cope).—Five were caught near King Lake in its outlet. A few were taken from the channel connecting two of the Bawbeese lakes.

Notropis cornutus (Mitchill). Shiner.—This species was found abundant at Beebe creek. I took thirty-five specimens, which measured from four to fifteen and one-half cm. in length.

Rhinichthys atronasus. Black-nosed Dace.—This minnow was found in the small brook in a pasture west of Reading avenue. Thirty were here taken. I am unable to determine whether these are *R. atronasus* (Mitchill) or *R. atronasus lunatus* (Cope).

Hybopsis kentuckiensis (Rafinesque). Horny Head.—Small individuals were found common at Beebe creek. Forty-five were taken at this place. They were from three to eight cm. in length.

Umbra limi (Kirtland). Mud Minnow.—Found abundant in the outlet of King Lake and in the pasture brook west of Reading avenue.

Lucius vermiculatus (LeSueur). Little Pickeral.—Found common in the outlet of King Lake and in Beebe creek. Six were taken, eight to twenty-one cm. long. I have seen this fish in a number of other streams and it is common in the region.

Fundulus dispar (Agassiz).—Two were taken August 28, 1902, in a few inches of water near the shore of Bawbeese Lake.

Labidesthes sicculus (Cope). Brook Silversides.—Found very common at Bawbeese Lake, swimming in large schools near the surface of shallow water. Two were taken at Beebe creek.

Pomoxis sparoides (Lacépède). Calico Bass.—Very common in the lakes about Hillsdale, where it is usually known as the speckled bass. It is especially abundant in King Lake. Ten small specimens, five to seven and one-half cm. long were taken at Beebe creek.

Ambloplytes rupestris (Rafinesque). Common Rock Bass.—Four small specimens, four and one-half cm. long, taken at Beebe creek. The fish is common at Bawbeese Lake. Its favorite haunts in this lake seems to be shallow water where there is a growth of rushes.

Chaenobryttus gulosus (Cuvier and Valenciennes). The Goggle Eye.—I caught ten, measuring from nine to fourteen cm. long by hook and line from King Lake, Bawbeese Lake, and Stock's mill pond. The fish is common in shallow weedy parts of the lakes about Hillsdale.

Apomotis cyanellus (Rafinesque). Blue-spotted Sunfish.—Seven were taken, measuring three and one-half to fourteen cm., from Bawbeese Lake, King Lake and Beebe creek.

Lepomis pallidus (Mitchill). Blue-gill.—A large number of these were taken from Bawbeese Lake and King Lake by hook and line, but only twenty-one of the smaller ones were preserved. These measured twenty-three to eighteen and one-half cm. The blue-gill is a very common fish about Hillsdale, and is a popular game fish, and takes a hook baited with worm readily.

Eupomotis gibbosus (Linnaeus). Common Sunfish.—Seven were taken from Bawbeese Lake and King Lake. These were from seven to thirteen cm. long. The species is common in the vicinity of Hillsdale.

Micropterus salmoides (Lacépède). Large-mouth Black Bass.—Eighteen specimens were preserved, which measured from five to twenty-two cm. This is an important game fish in the lakes about Hillsdale, and it grows to a good size in the region. The largest one that I have seen taken near Hillsdale weighed about five pounds.

Perca flavescens (Mitchill). Yellow Perch.—Many were caught from Bawbeese Lake, but only seven were preserved. It is abundant in Bawbeese Lake and in Stock's mill pond.

Hadropterus aspro (Cope and Jordan). Black-sided Darter.—Two specimens, five to seven and one-half cm. long, were taken from Beebe creek.

Boleosoma nigrum (Rafinesque). Johnny Darter.—Six were taken at Beebe creek, which were from four and one-half to eight and one-half cm. long. I also took four from the small stream near Allen.

Etheostoma caeruleum (Storer). Blue Darter.—This is a very common darter in Beebe creek and in the outlet of King Lake and in some other streams of the region. About a hundred were caught. They were from three to nine and one-fourth cm. in length.

The above list gives the fishes, which I have actually taken in the county and identified, but there are several other species which I know to be in the region. The eel, *Anguilla chrysypa*, is often speared in Bawbeese lake. The whitefish, probably *Coregonus clupeiformis*, is said to be in Bawbeese lake. I have seen brook trout, *Salvelinus fontinalis*, taken from the stream, which runs through Hillsdale. There is a large game fish that is much sought for in the lakes about Hillsdale, known as the pickeral. This is probably *Lucius lucius*.

State Normal School, Charleston, Illinois.

LABORATORY WORK AND ITS RELATION TO FIELD WORK. (ABSTRACT.)

J. G. NEEDHAM.

The adjustment of field work and laboratory work in any course in biology should proceed upon the assumption that these are complemental and not antagonistic. Their method does not differ necessarily, but only the conditions under which they are carried on. Either may be static or dynamic according to the purpose for which it is used. Both are necessary for the rounding out of most biological inquiries. Both are means, not ends, and should be used accordingly as they serve a pedagogical purpose of the work in hand.

The laboratory has certain great advantages for any work which may be carried on within it. Some of these arise out of our psychological and physical limitations. The laboratory has a roof and a floor and is usable in all weather. It has walls which shut out distractions. It has tables and chairs whereon we may dispose our members and our implements; and it has conveniences for assembling around us, while we work, more apparatus and reagents than would be manageable otherwise. Furthermore, it has means of control of light and heat and other forces, useful in experimentation, which cannot be had outside its walls.

These advantages are so great that we take our work into the laboratory whenever possible. There are, however, certain phases of ecology, distribution studies and all studies of life in relation to environment *in extenso,* that may not be done within the laboratory, just as there are studies, like histology, which can make no progress apart from laboratory equipment. However, most biological, even most ecological studies, are furthered by the concurrent, and complemental use, of both field and laboratory methods; for each method will inevitably raise questions best answered by the other.

Life in action is studied in the field; mechanisms and adjustments are worked out in the laboratory. In general, the field gives us our broad conceptions, the laboratory our nearer and clearer views.

Lake Forest, Ills.

LABORATORY WORK IN BIOLOGY, ITS NATURE, CONDUCT AND VALUE* (ABSTRACT.)

LOUIS MURBACH.

Biology was introduced into high schools mostly at the instance of colleges when it was established in the higher institutions. First it was allowed, then required for college entrance and was naturally shaped after college work. Recently it is being held that biology should be taught in secondary schools in such a way as to be a part of their scheme of giving a more liberal education—to better realize his position in nature—to the youth who cannot hope to go to college.

There is probably as much difference in the nature of laboratory work in biology as there are teachers teaching it, although at first thought there might not seem to be much difference so long as it is laboratory work. Being directed to find certain things in a specimen, and how they "look," and what is their significance is one kind of laboratory work. It is still current in colleges and does less harm there than in the high school. It is a great way in advance of the older text-book method. The pupil becomes a verifier; if he ever attains to more he may thank some innate genius or change of environment.

To begin with, then, specimens are to be placed in the hands of all pupils. Mere observations and descriptions of specimens is not a very enlivening work, but may be made more so by the introduction of experiments that bear on the nature of the specimens studied. It is assumed that both the observational work and experiments will be followed by reading and discussion. Study many specimens, at least in the way of comparison, but require only one or two to be drawn and described. So in experiments, there should be as many as can be done though only the principal one need be written out. Drawing the apparatus used in experiments is time put in that might be better employed. Nearly half the course should be laboratory work, strictly considered. This would leave the other half to be divided between ecological or field work and book work, including the discussion or recitation.

Nearly half the time of any study, especially in the lower grade of the high school, should be for the training of the observation, manual dexterity, and the judgment. To further this end the work should be carefully graded and carefully worded. Only those things that are beyond the pupil's comprehension should be told him, and then in such a way that he will understand that it is not his own idea; and, what is of no less importance, he should be early taught how to express or to show in his record, what is his own observation or inference and what he has from the book or from his teacher.

*Presented before Science Teaching Section of Mich. Academy of Science, March, 1906.

The laboratory books that give ready-made observations and conclusions for secondary schools are still numerous. This alone would be sufficient reason for every teacher making his own laboratory book. . . . *Most of the biological work laid out for second year high school pupils should be simpler.* . . . The ideal way would be to have so few students that we might give each student much individual attention. With our large numbers we are compelled to adopt more formal methods, and our pupils are reduced to one level which, I fear, is much below what the best in the class could do. Even if we have such simple and explicit directions that the majority can work along somewhat independently, the quality and quantity of work will be below the standard of the better members of the class. We reduce to a common level rather than educate.

We cannot give a pupil all the information that he will need in the future. It would seem better to train him to get information for himself after he has left our sphere. This training will incidentally be half information. Furthermore, mere observation work is not going to do this. After comparisons are made, inferences should be required. And wherever this is susceptible of proof, experiments should be introduced.

All through, both the observations and the experiments must be graded. This does not mean as the science work is arranged in grammar schools, but both observations and experiments must be led up to, or the mind of the pupil prepared for the work. This need not necessarily be done in the book or guide, but may be the part of a good teacher.

"The way" is of more importance than the subjects or the amount of work done. Every observation that is carefully made will assure the observer after each comparison, and lead to more certain knowledge. It gives encouragement to continue along the same line, and engenders confidence in the pupil's ability to try other things. He gains mental traits that cannot be replaced by any amount of mere information, not his own. He has had the contact that gives faith founded on experience. Besides furnishing a way of acquiring new facts, it furnishes a way of testing information that seems to be open to question.

Detroit, Michigan.

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ERRATUM.

Page 10, line 1, "Eleventh" read "Twelfth."

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